



US009437361B2

(12) **United States Patent**  
**Honna**

(10) **Patent No.:** **US 9,437,361 B2**  
(45) **Date of Patent:** **Sep. 6, 2016**

(54) **THREE-PHASE HIGH FREQUENCY TRANSFORMER**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 910 days.

(21) Appl. No.: **13/060,519**

(22) PCT Filed: **Aug. 18, 2009**

(86) PCT No.: **PCT/JP2009/064448**

§ 371 (c)(1),

(2), (4) Date: **Feb. 24, 2011**

(87) PCT Pub. No.: **WO2010/024153**

PCT Pub. Date: **Mar. 4, 2010**

(65) **Prior Publication Data**

US 2011/0156851 A1 Jun. 30, 2011

(30) **Foreign Application Priority Data**

Aug. 25, 2008 (JP) ..... 2008-214993

Apr. 6, 2009 (JP) ..... 2009-092395

(51) **Int. Cl.**

**H01F 30/12** (2006.01)

**H01F 27/28** (2006.01)

**H01F 27/255** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01F 30/12** (2013.01); **H01F 27/255** (2013.01); **H01F 27/2847** (2013.01)

(58) **Field of Classification Search**

CPC ..... **H01F 27/255**; **H01F 30/12**

USPC ..... **336/5**

See application file for complete search history.

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*Primary Examiner* — Elvin G Enad

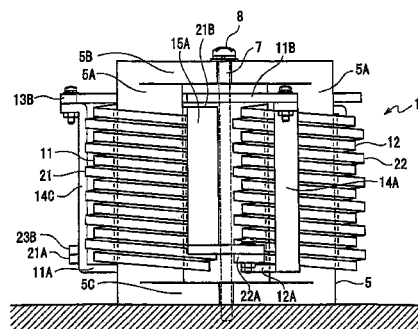
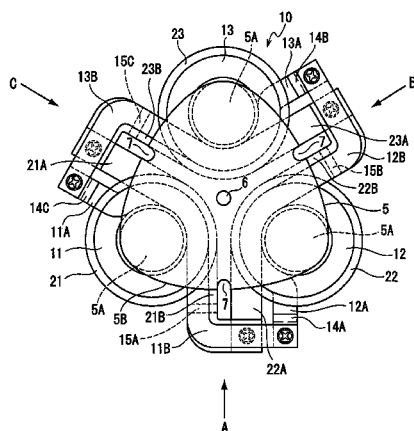
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(57) **ABSTRACT**

A three-phase high frequency transformer has: a ferrite core formed from three solid-cylindrical cores and a ceiling plate and a bottom plate; and three sets of coils having primary coils of a predetermined inner diameter that are formed by bending flat wires plural times in width directions of the flat wires, and secondary coils that are formed such that an inner diameter is the same as the inner diameter of the primary coils by bending flat wires, that have a width that is different than a width of the flat wires of the primary coils, in width directions of the flat wires, and the flat wires that structure the secondary coils are interposed within intervals of the flat wires that structure the primary coils, and the three sets of coils are structured such that inner peripheries of the primary coils and the secondary coils coincide, and are disposed such that the respective solid-cylindrical cores are inserted in respective inner portions, and the primary coils and the secondary coils are  $\Delta$ -connected or Y-connected.

**2 Claims, 45 Drawing Sheets**



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FIG.1A

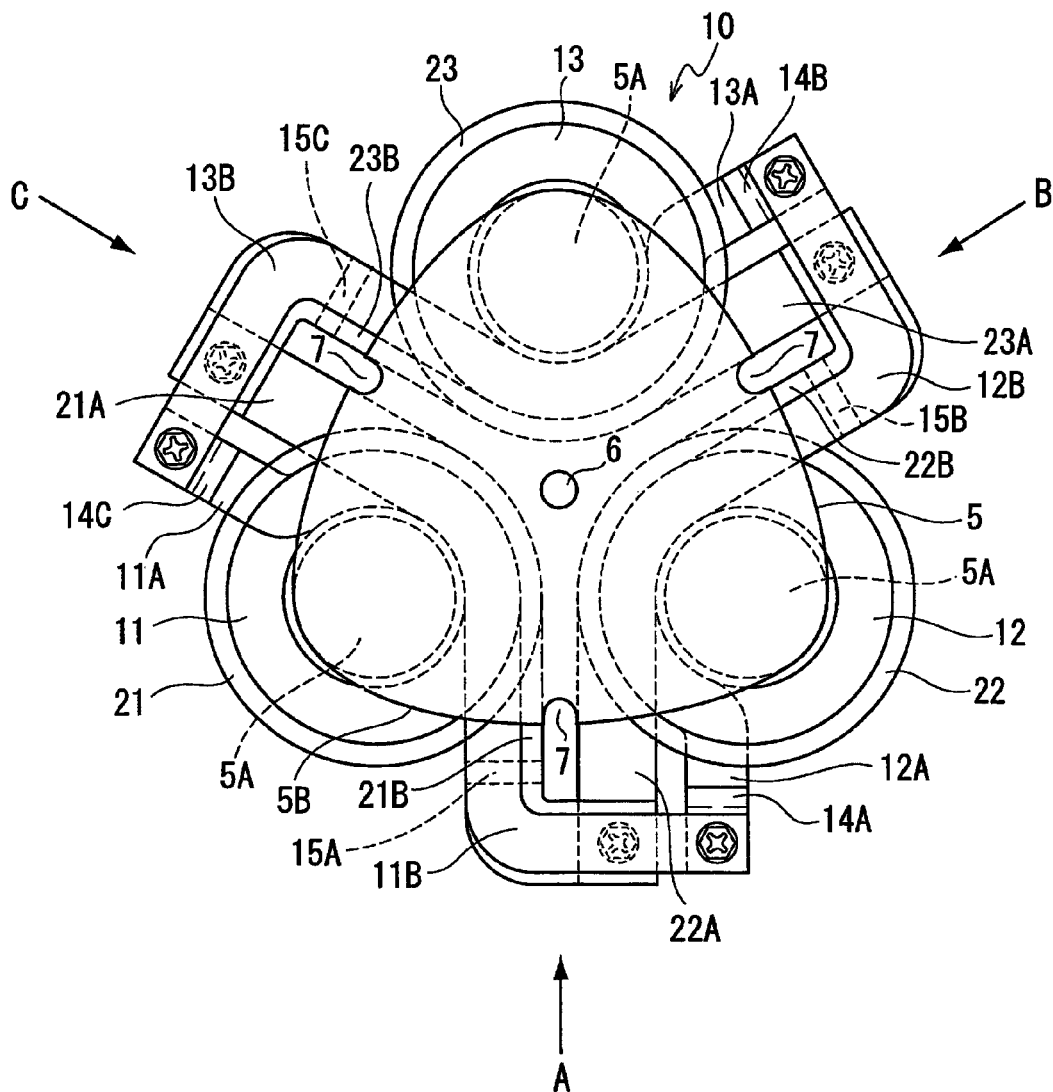


FIG. 1B

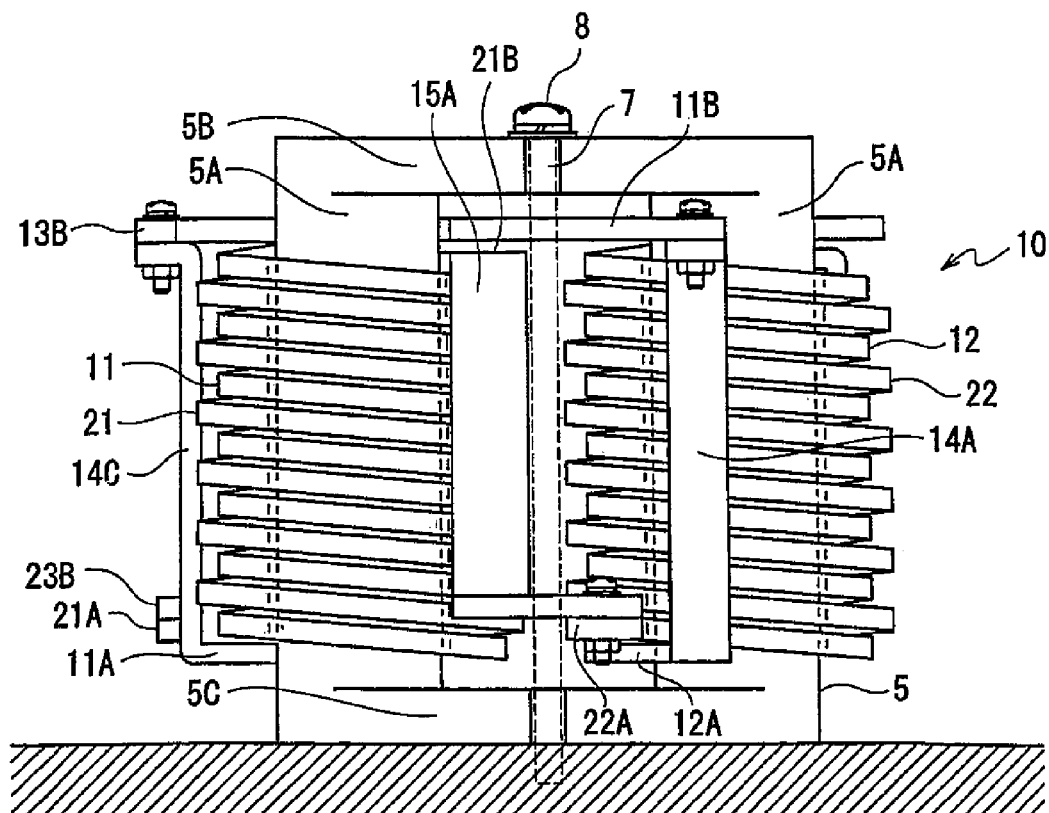


FIG. 1C

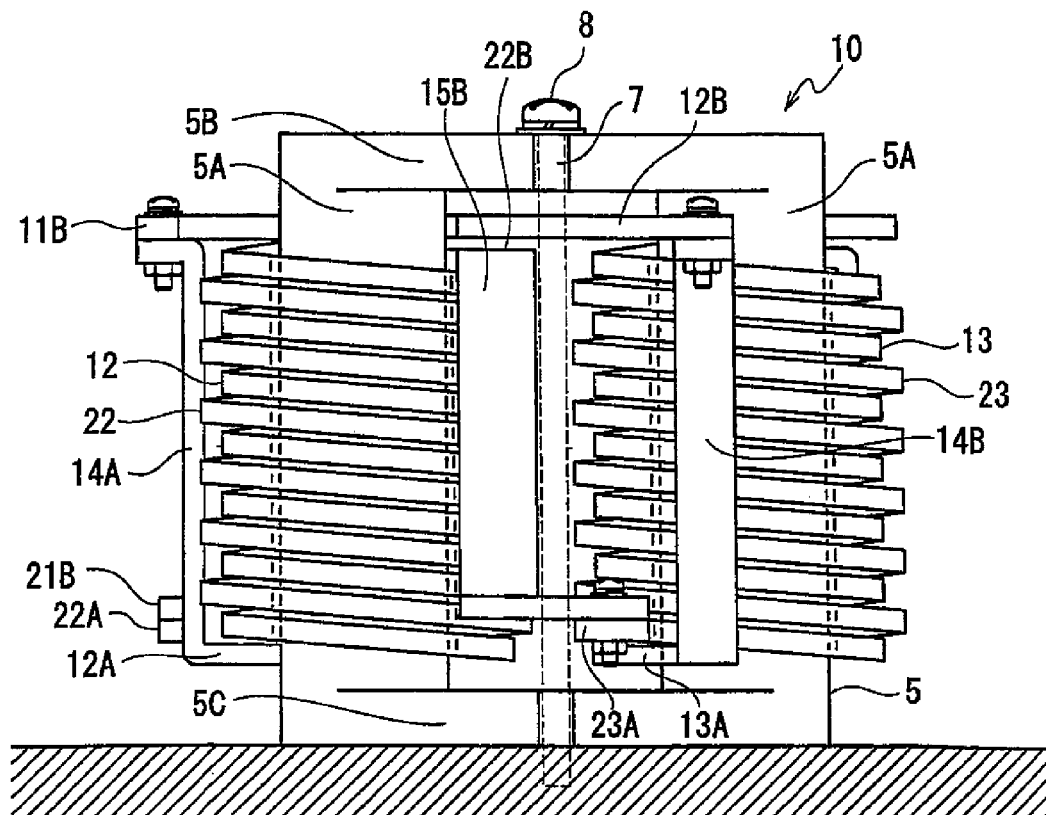


FIG. 1D

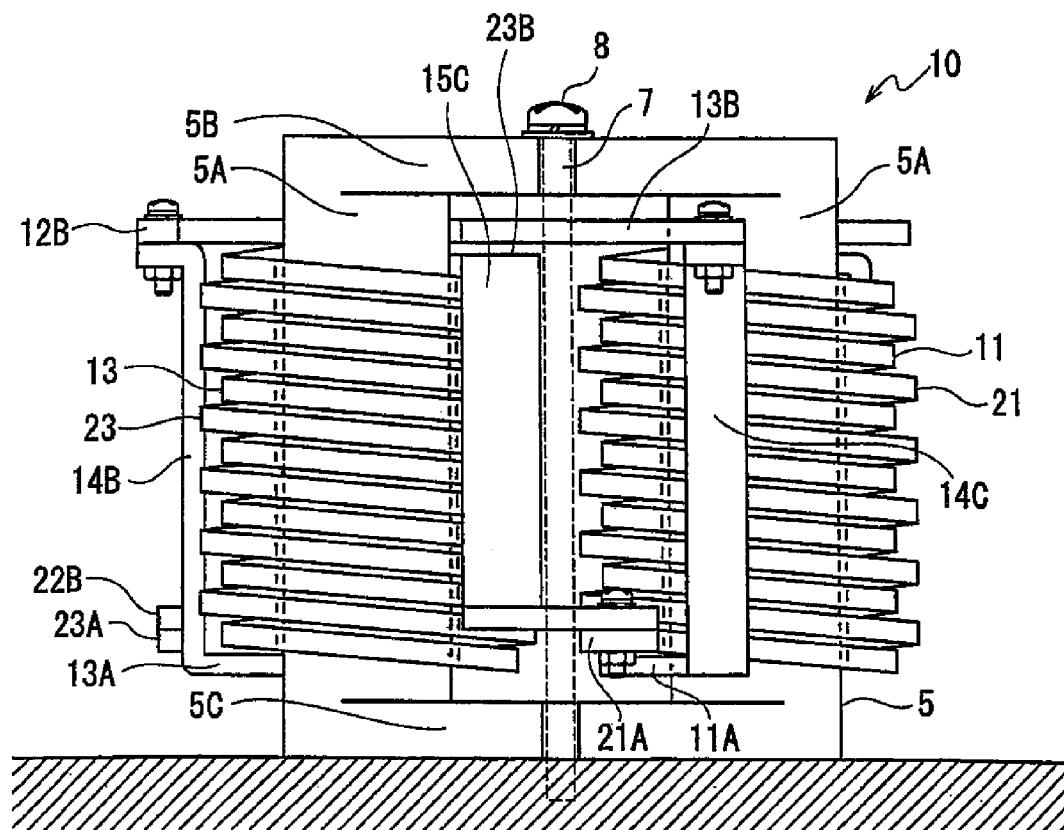
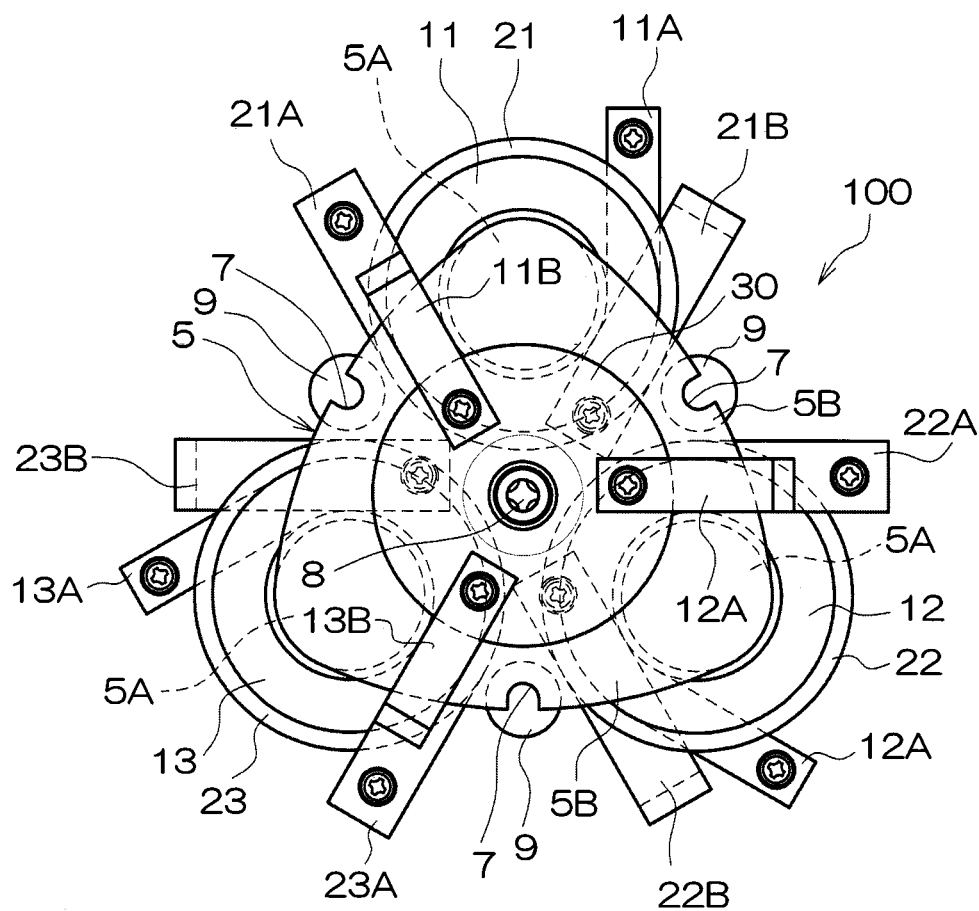


FIG.2A



**FIG.2B**

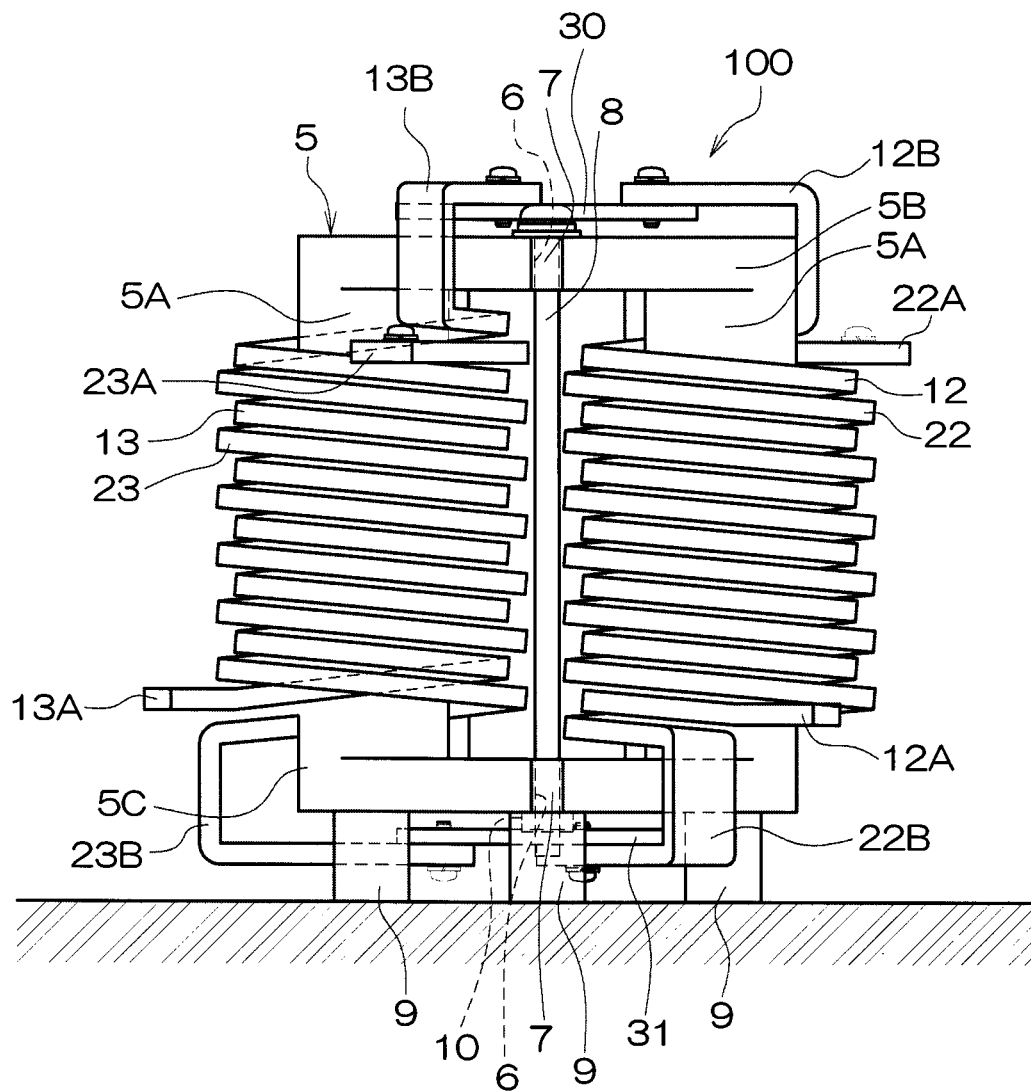




FIG.2C

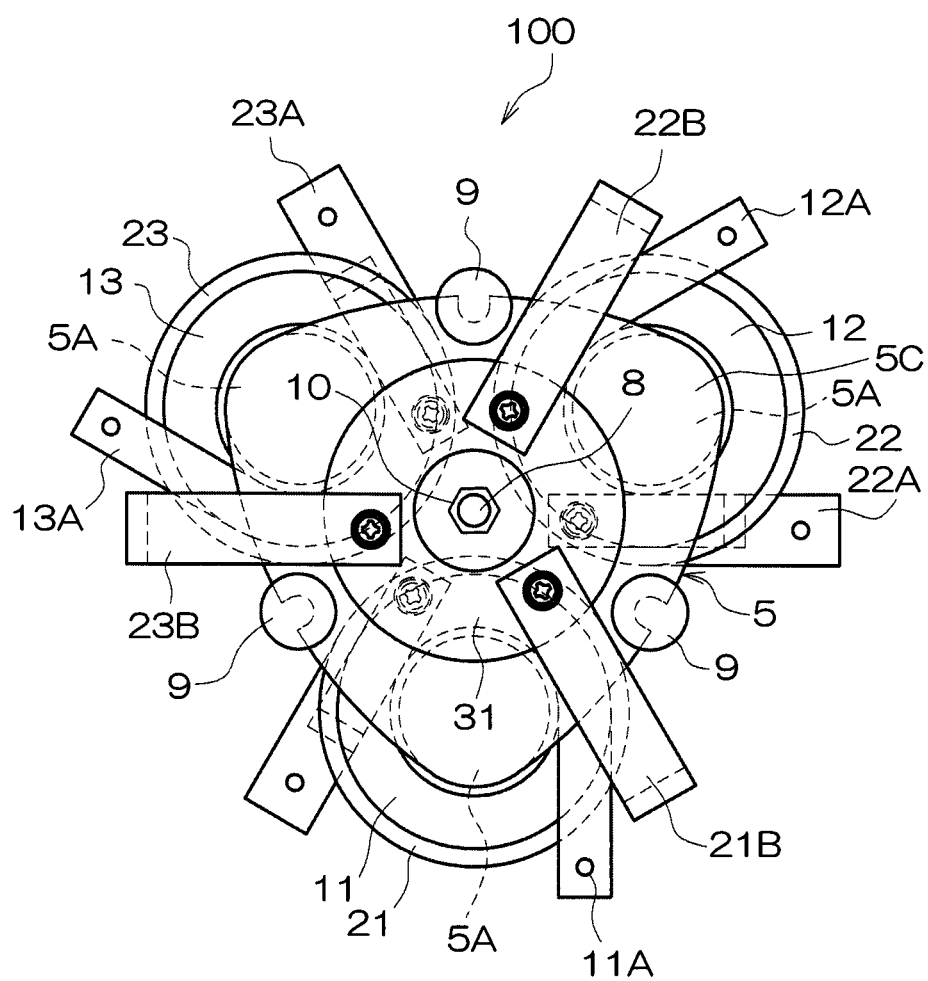


FIG.3A

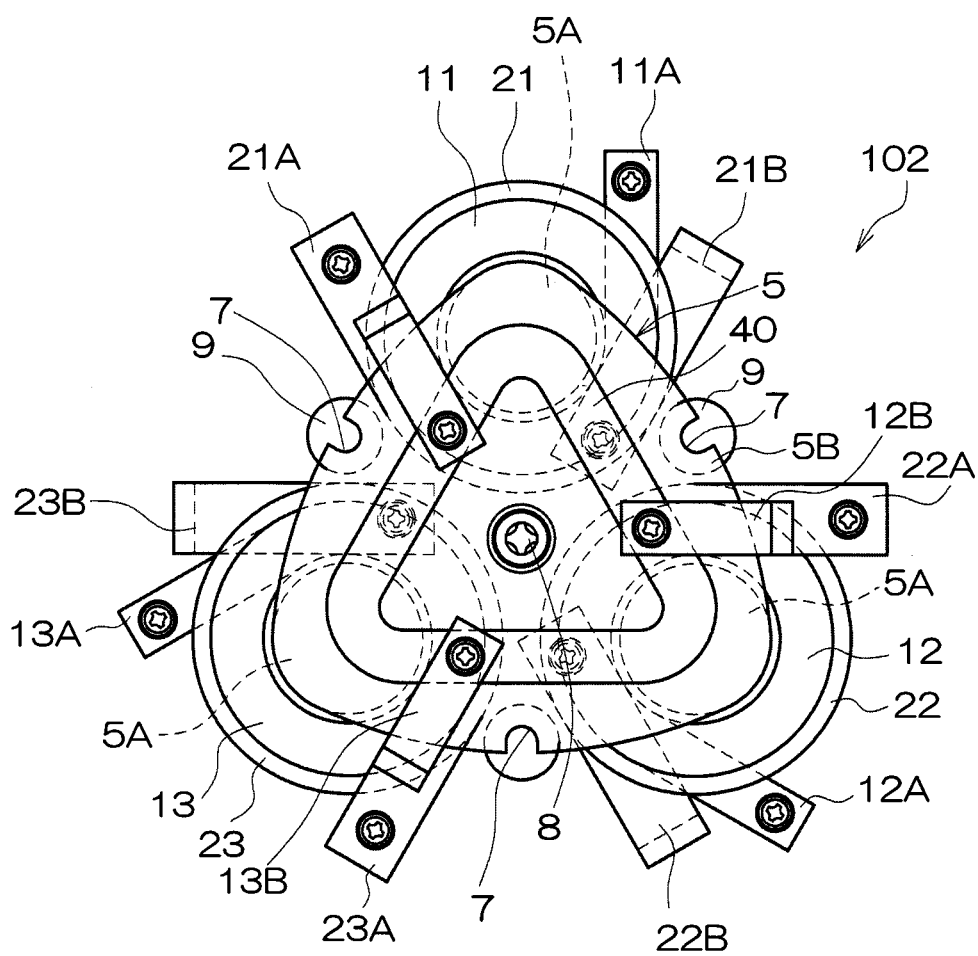


FIG.3B

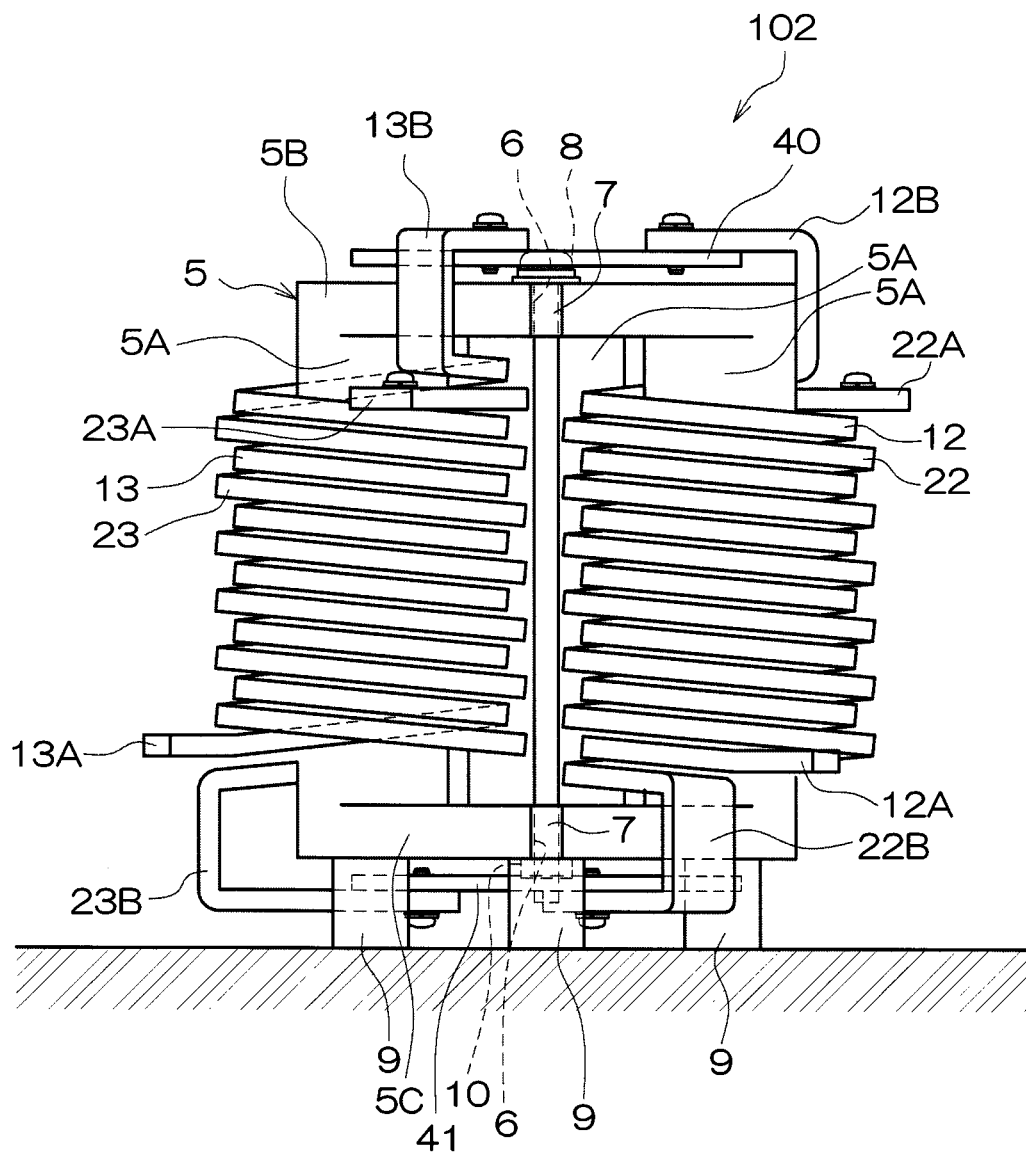


FIG.3C

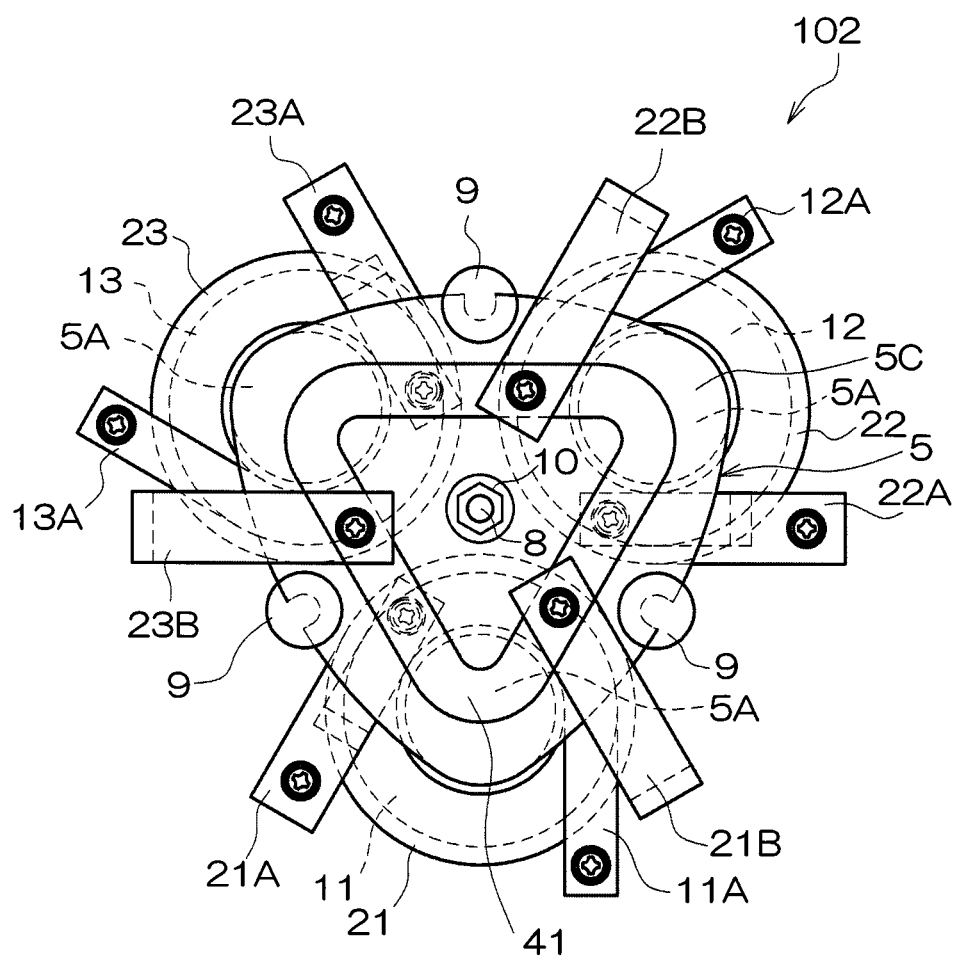


FIG.4A

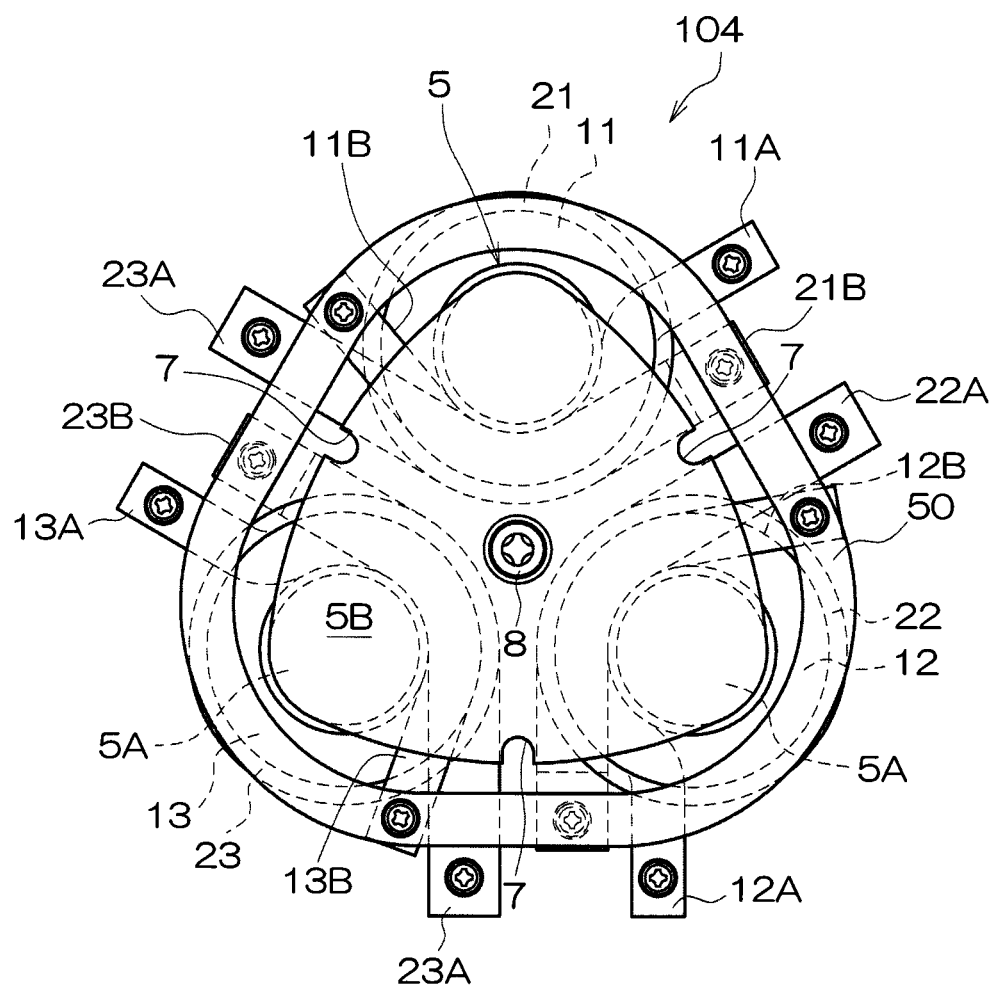


FIG.4B

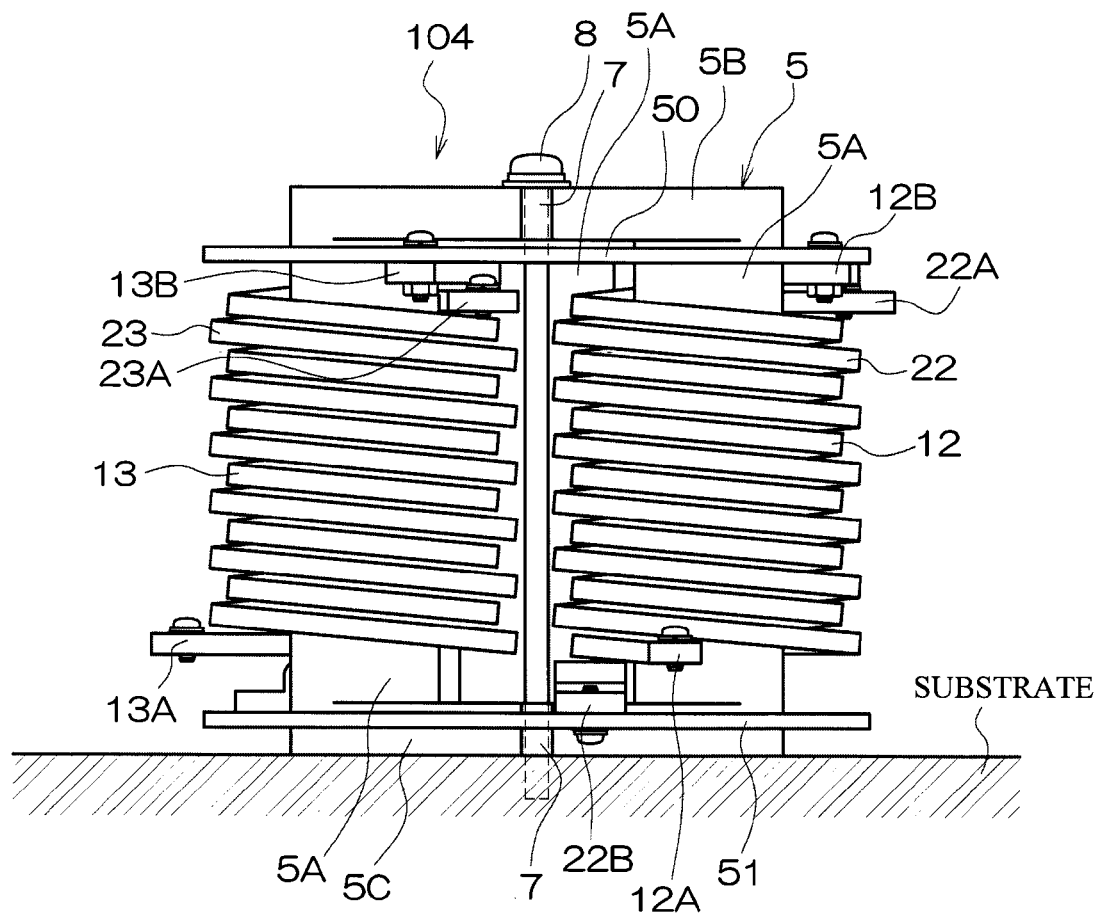


FIG.4C

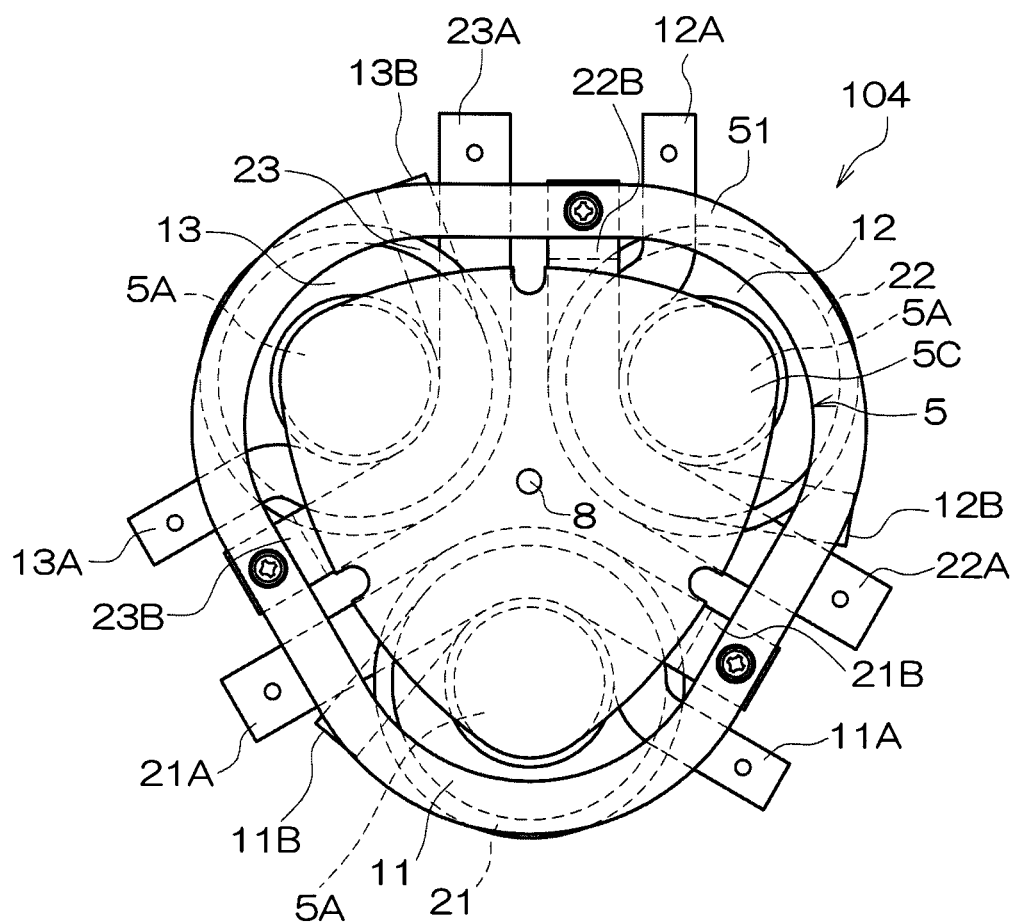


FIG.5A

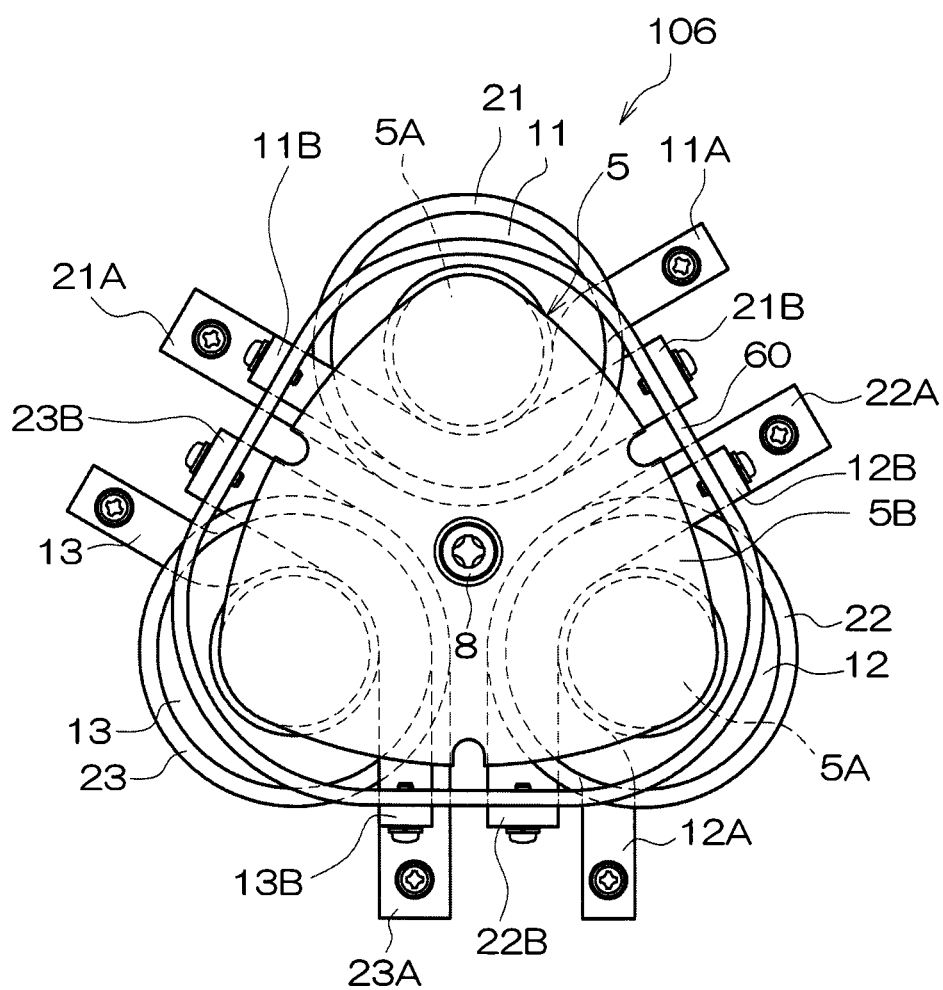




FIG.5B

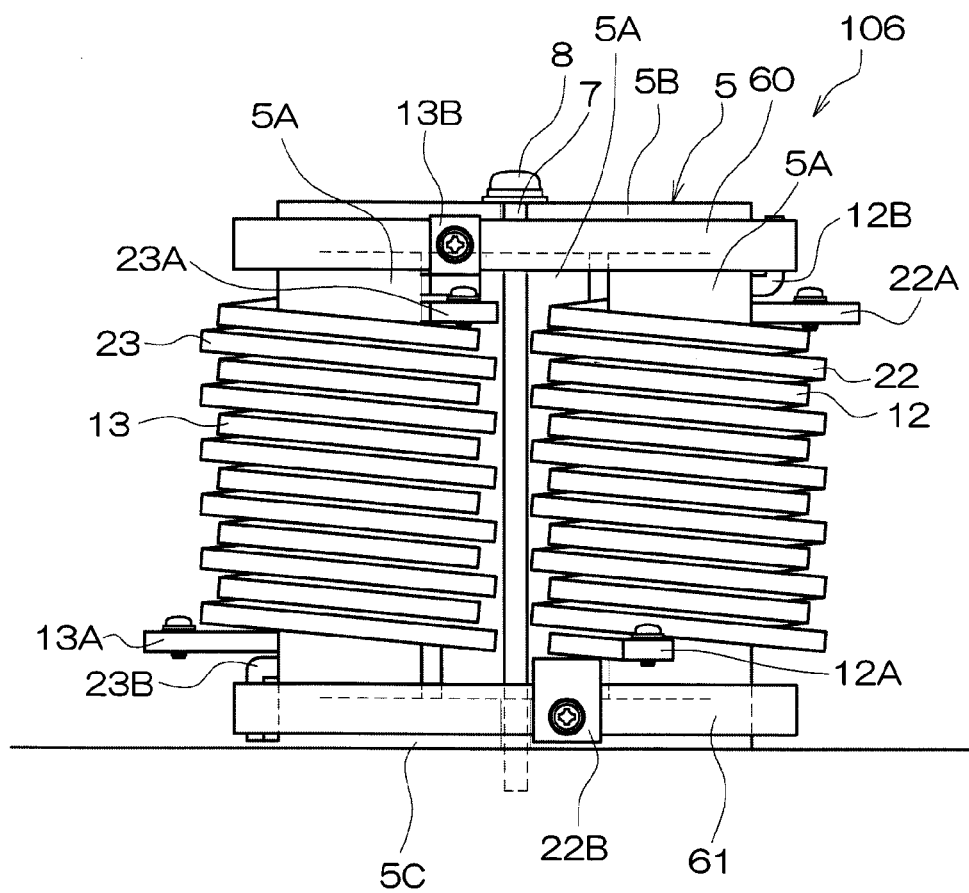


FIG.5C

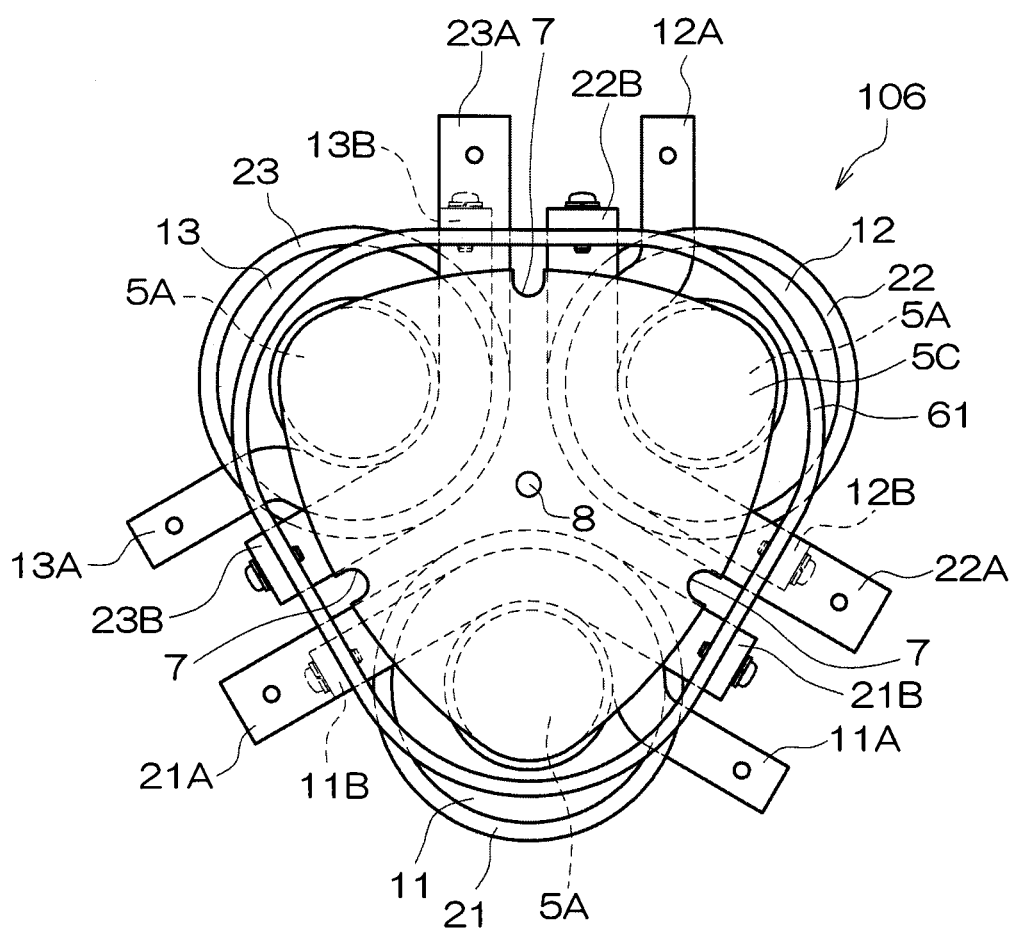


FIG.6A

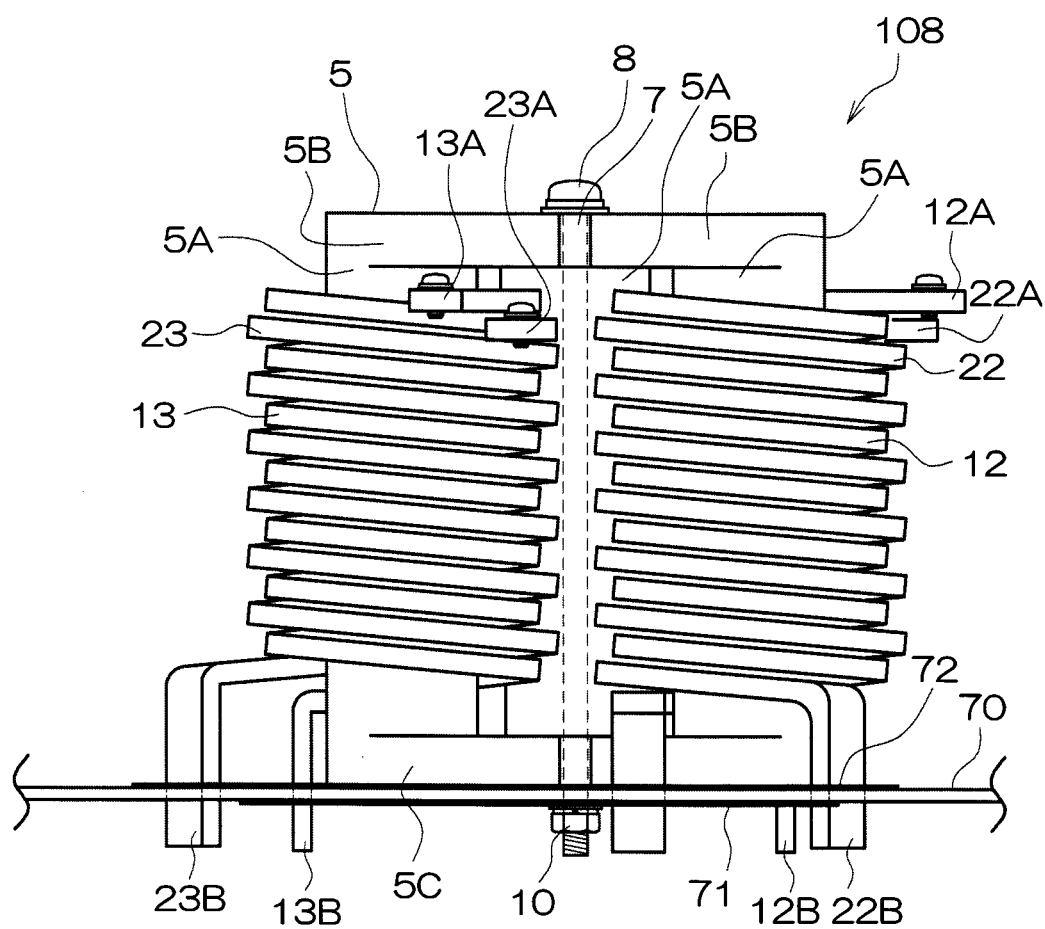


FIG.6B

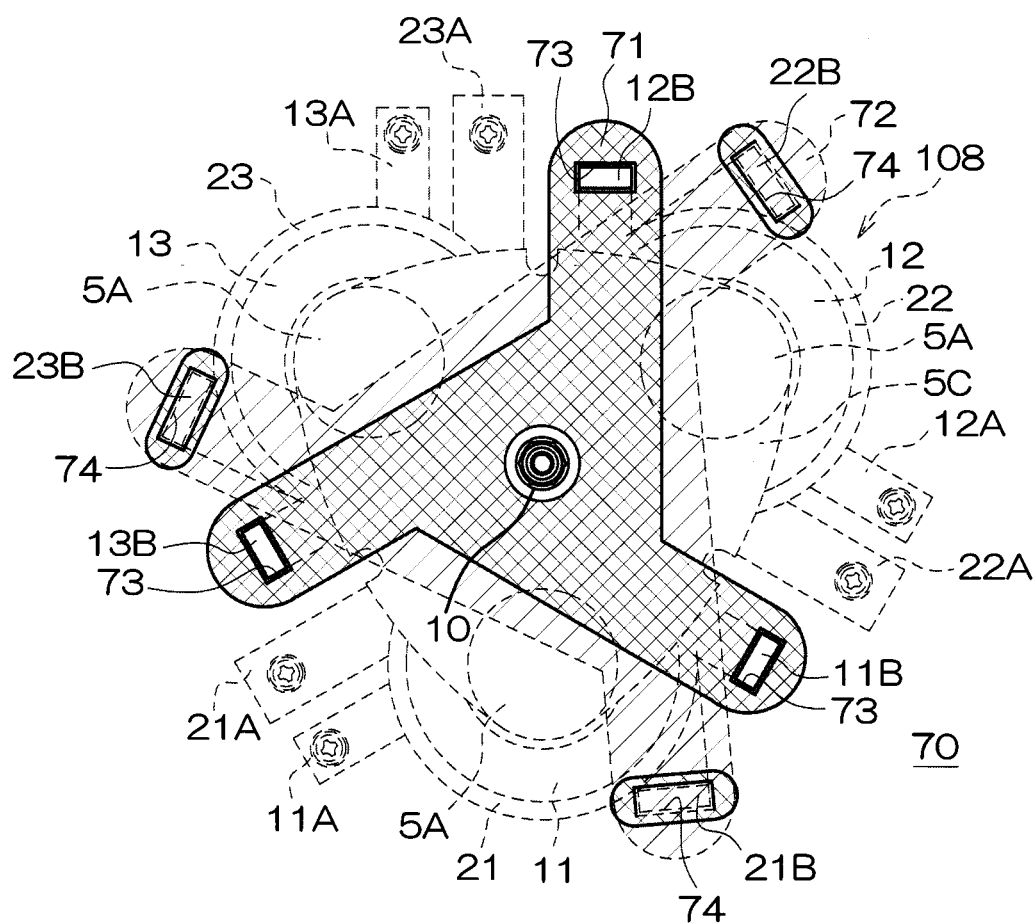


FIG.7A

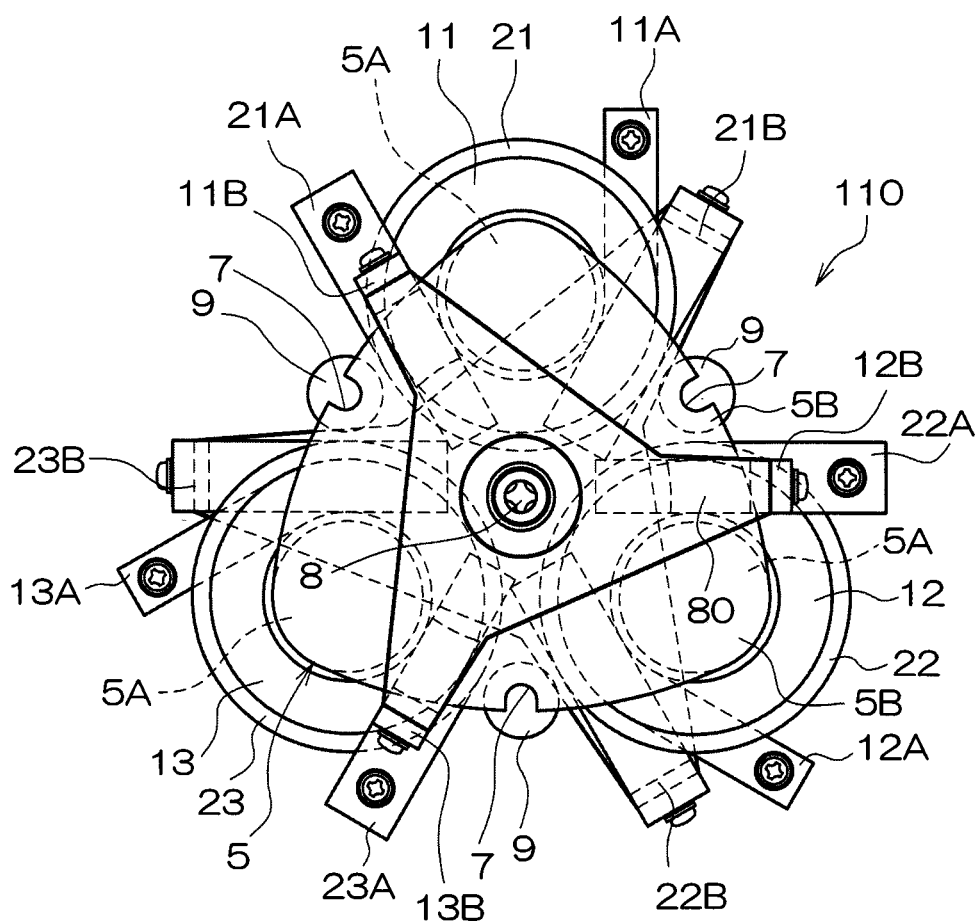


FIG. 7B

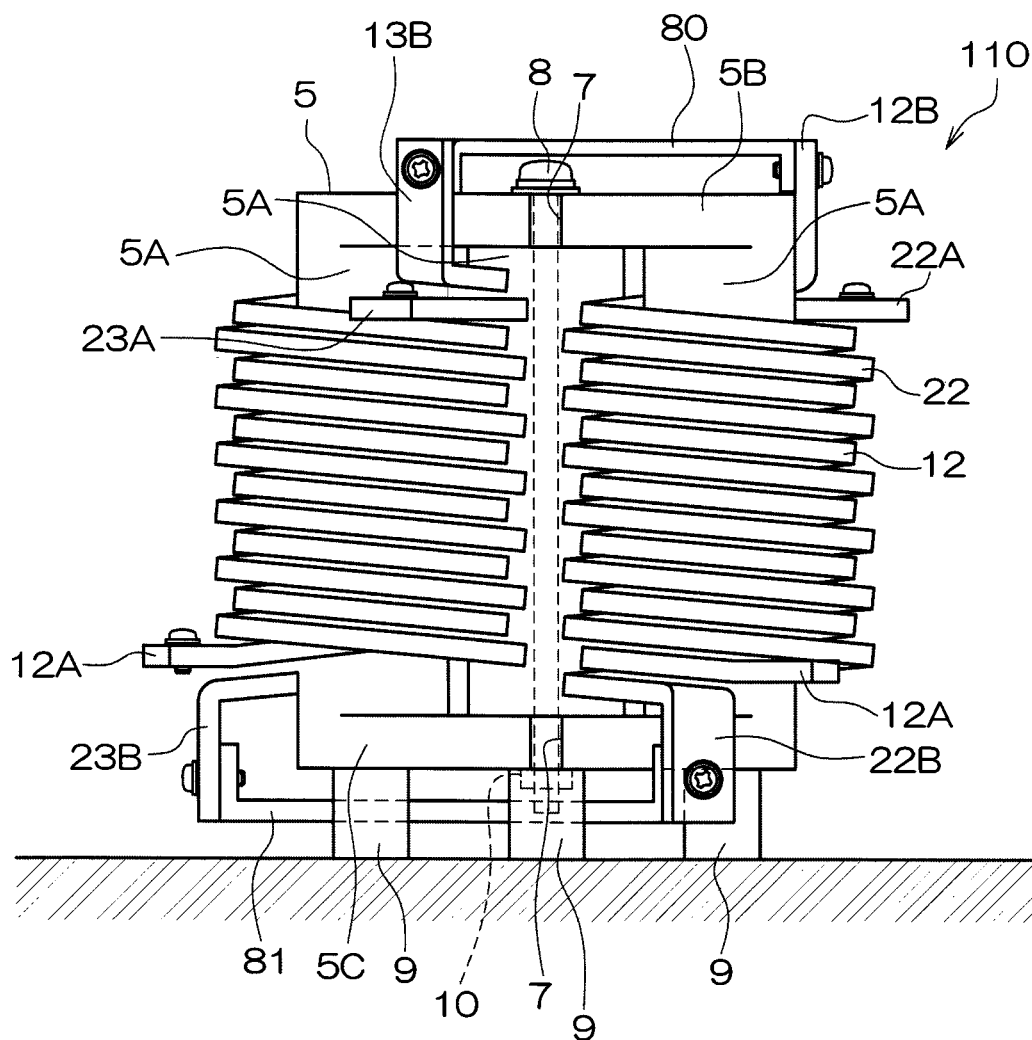


FIG. 7C

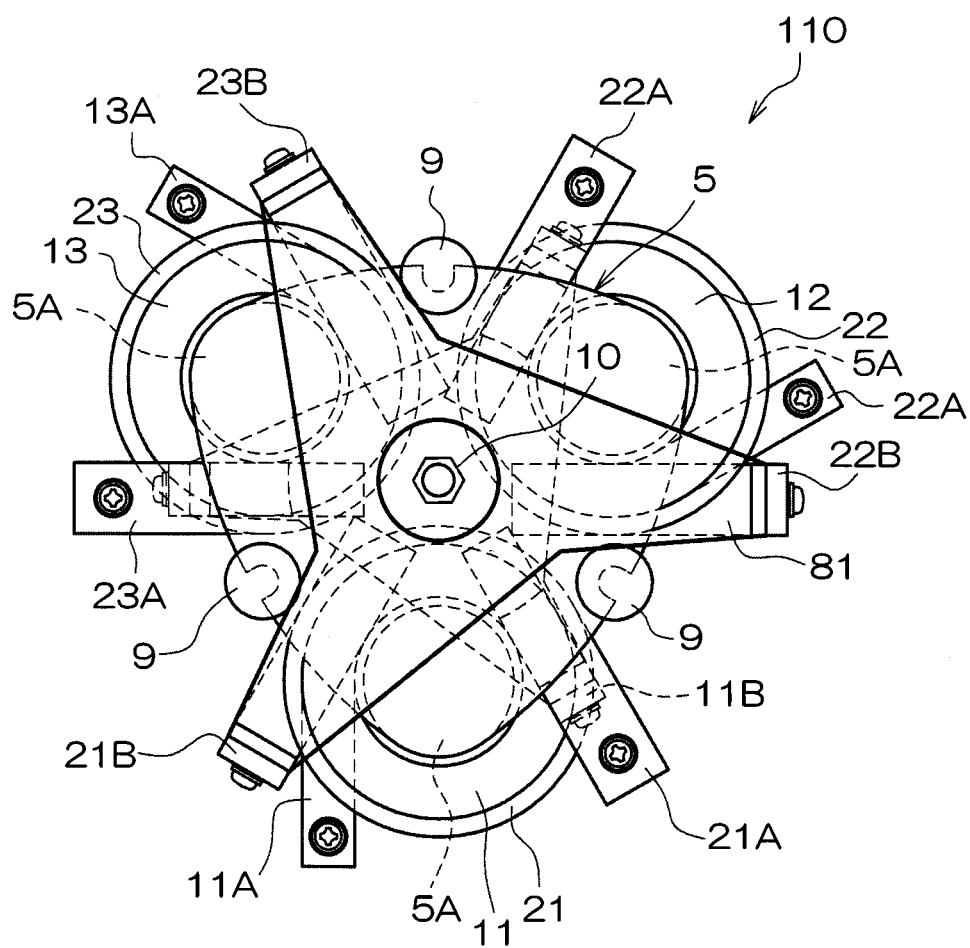


FIG.8A

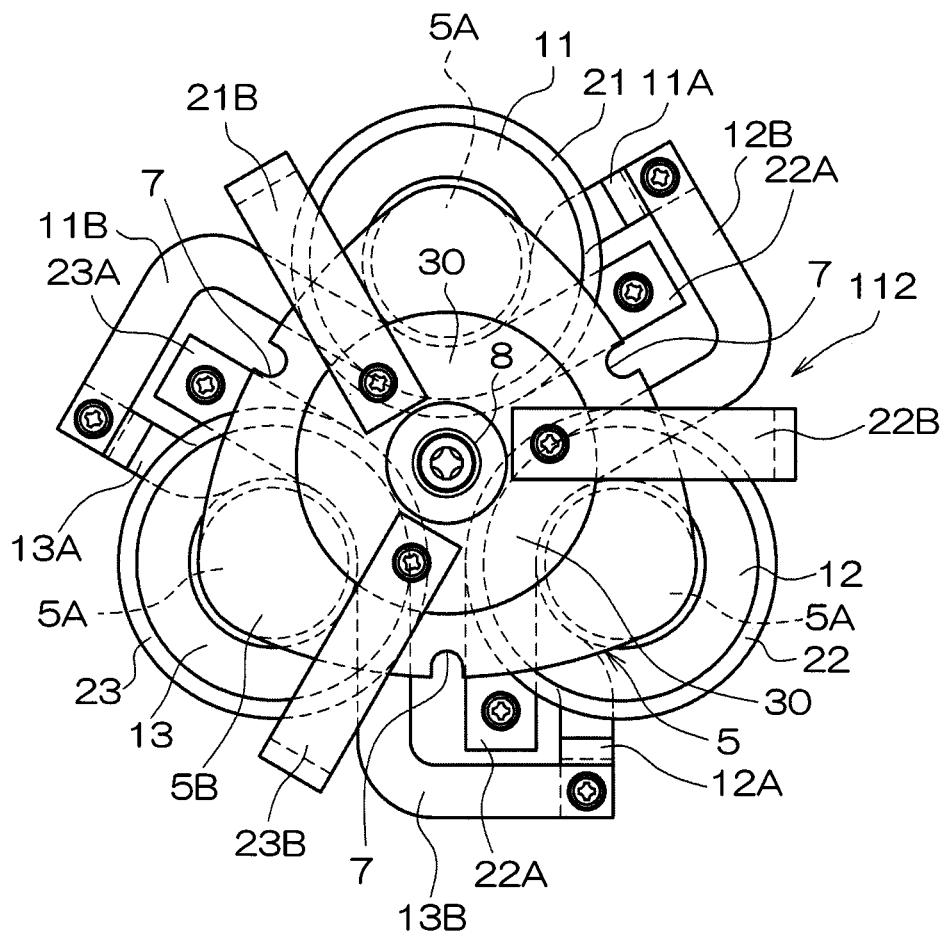




FIG.8B

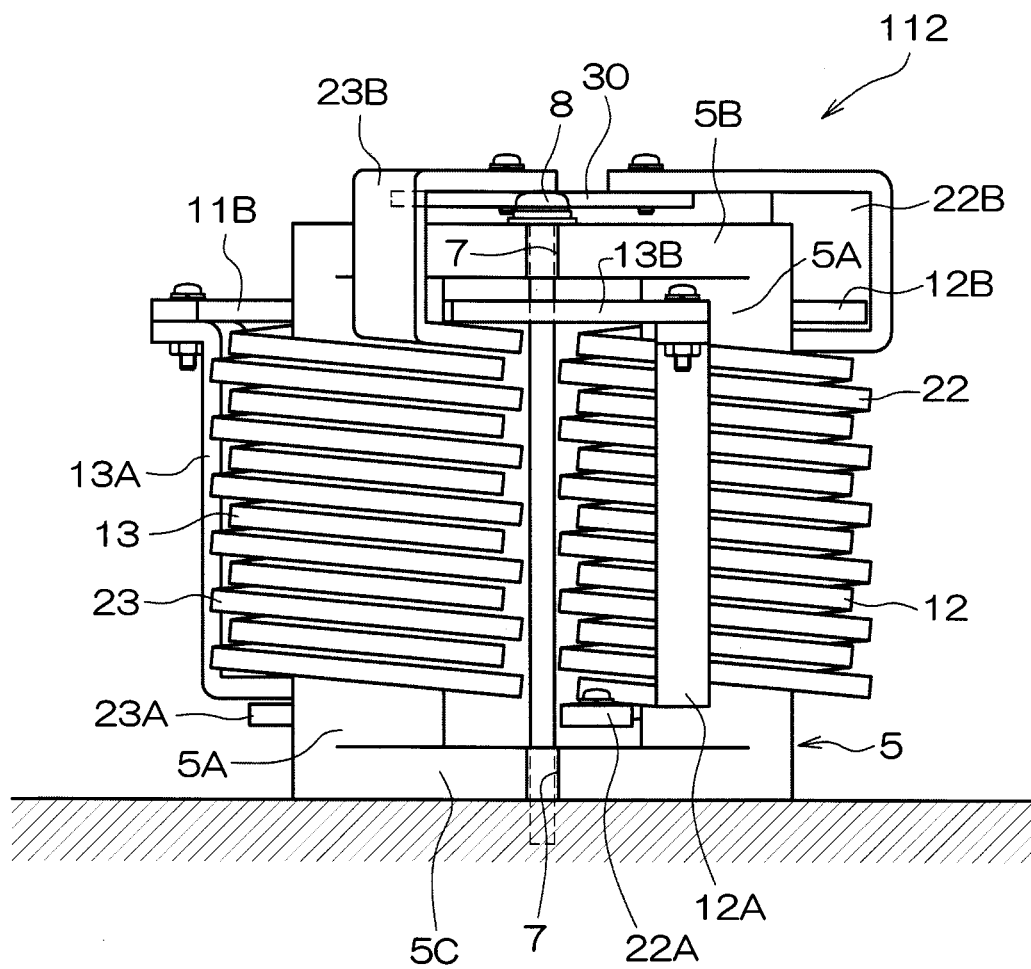


FIG.9A

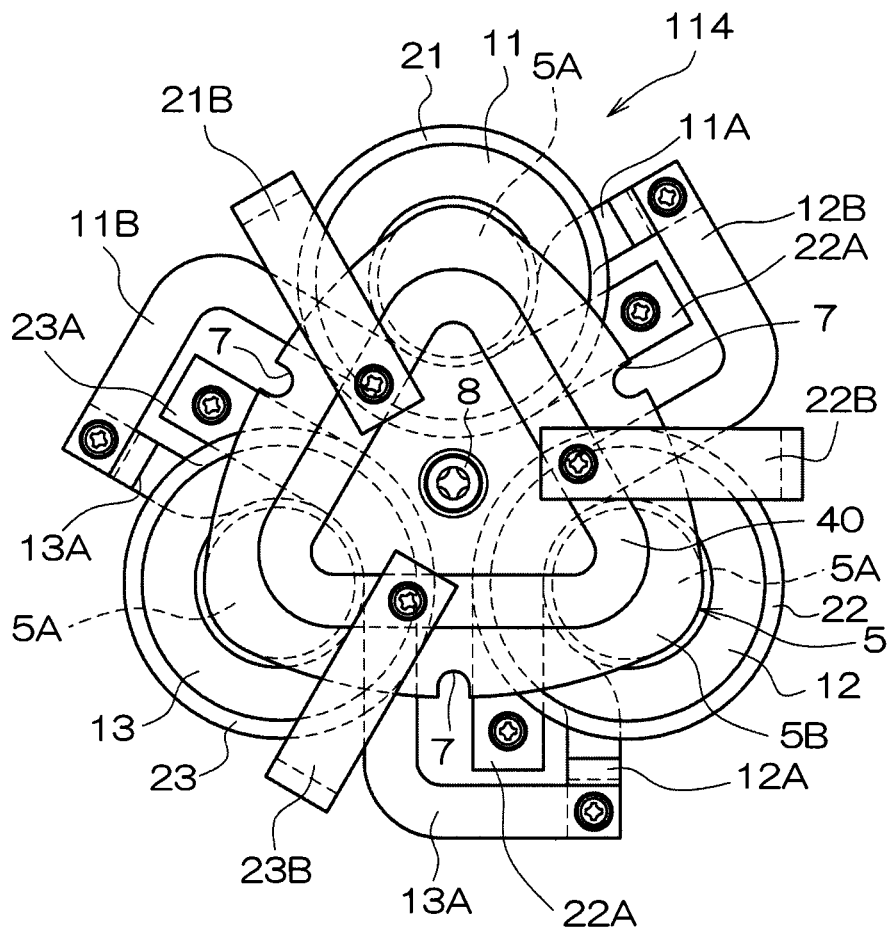


FIG.9B

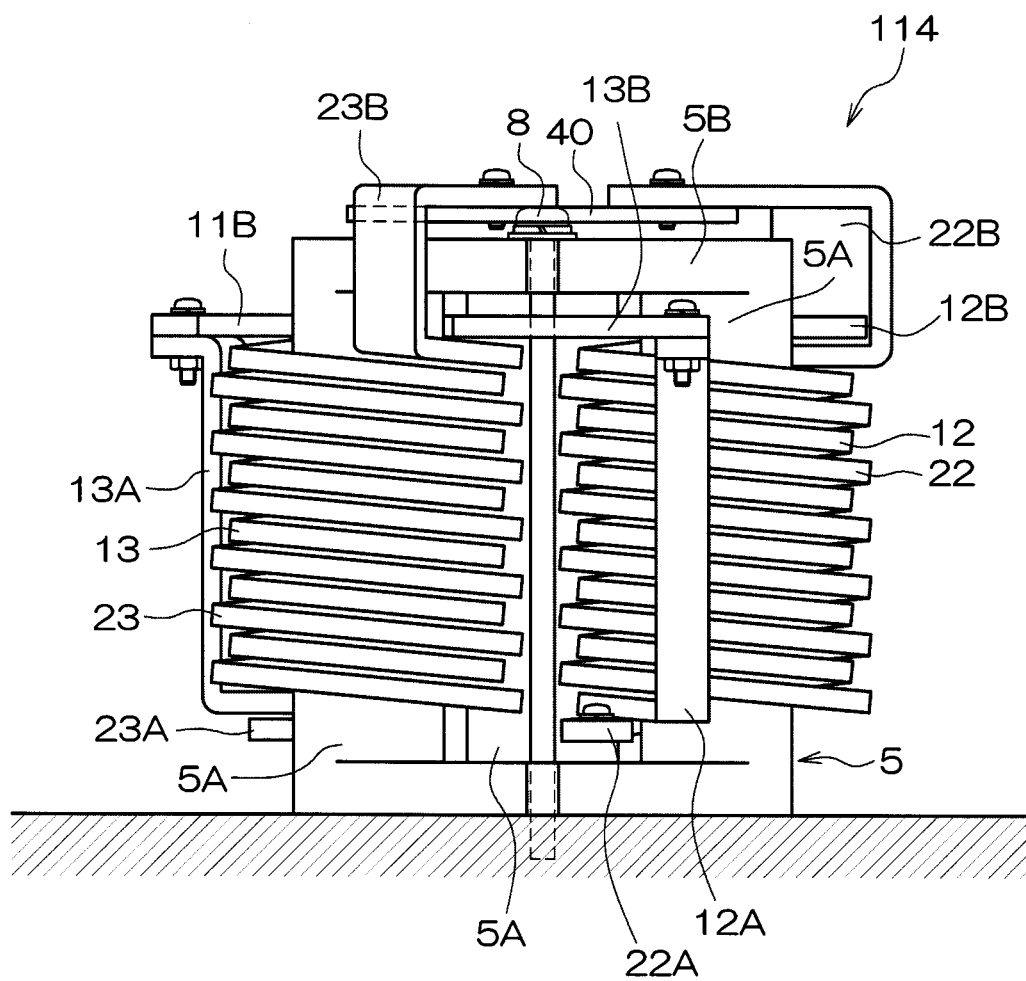


FIG.10A

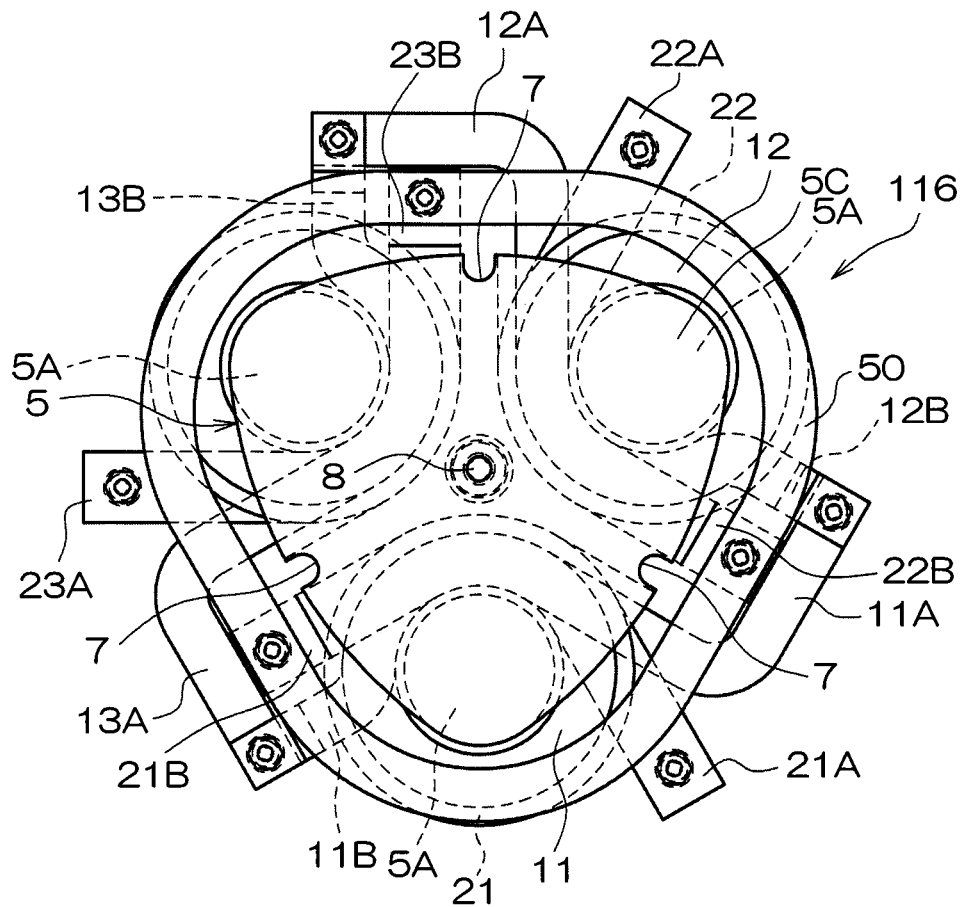


FIG.10B

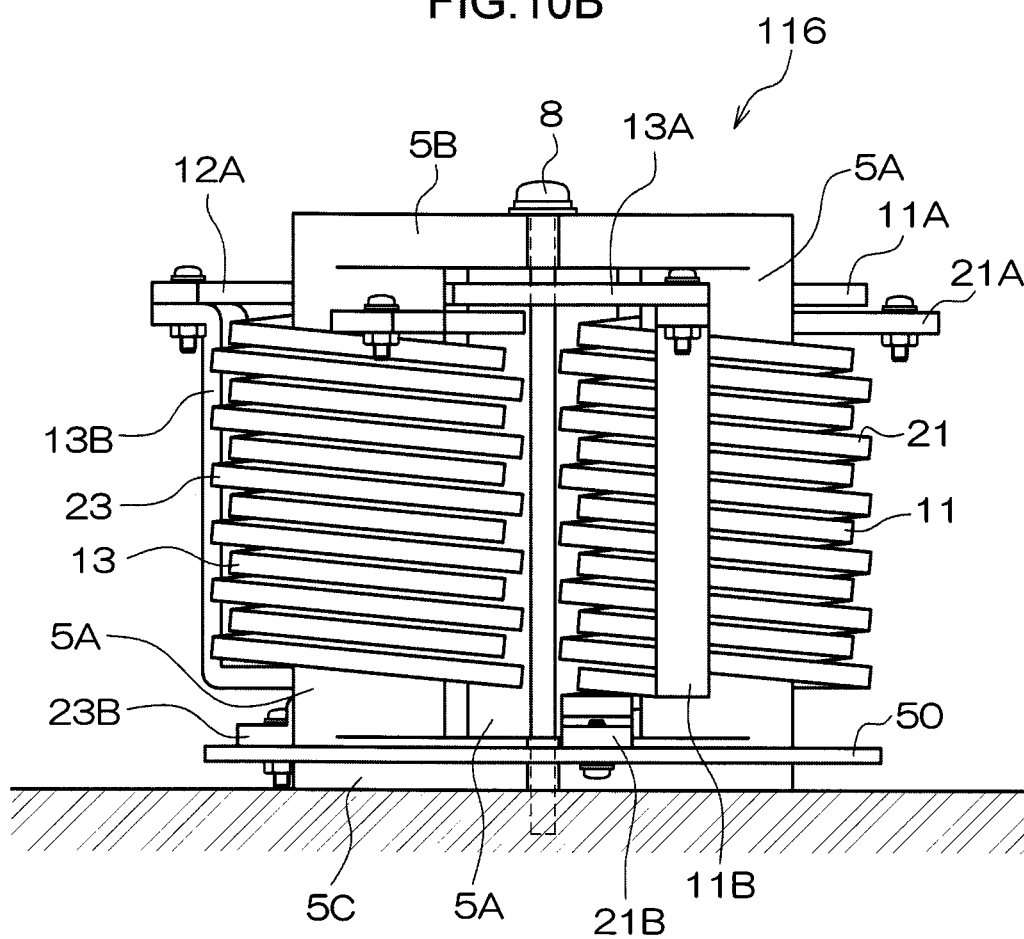


FIG.11A

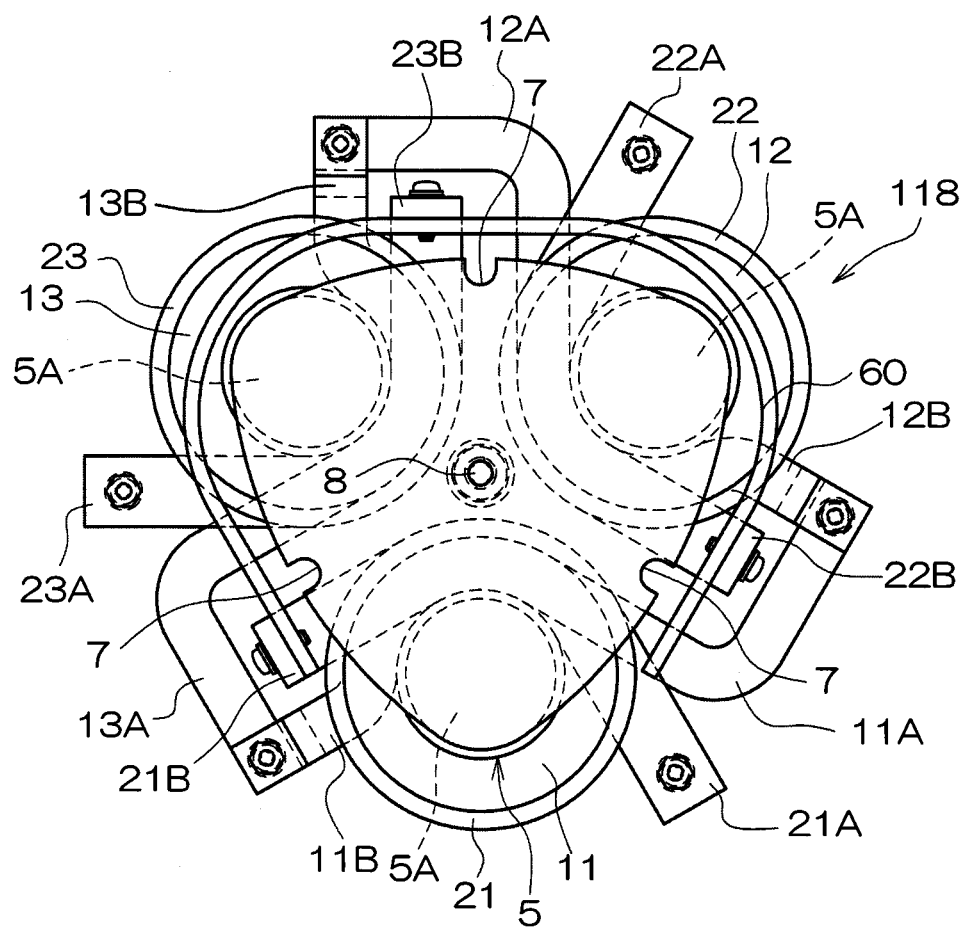


FIG.11B

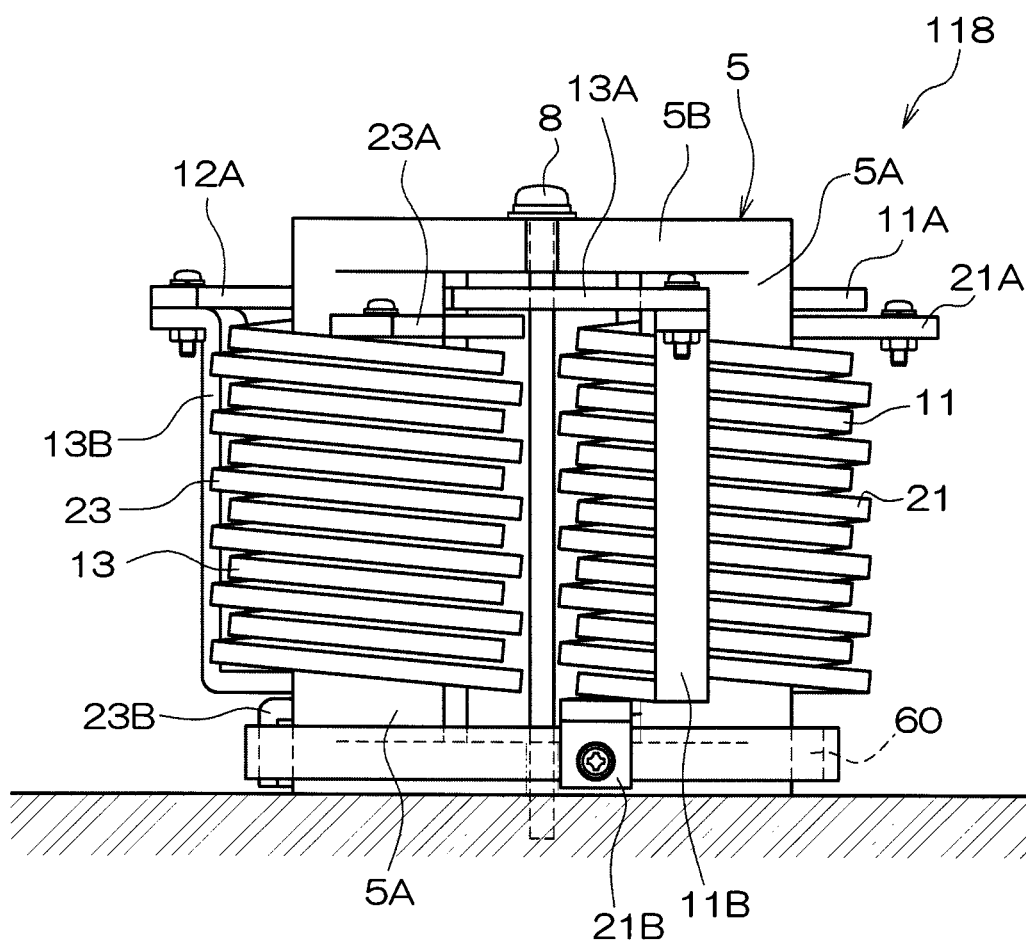


FIG.12A

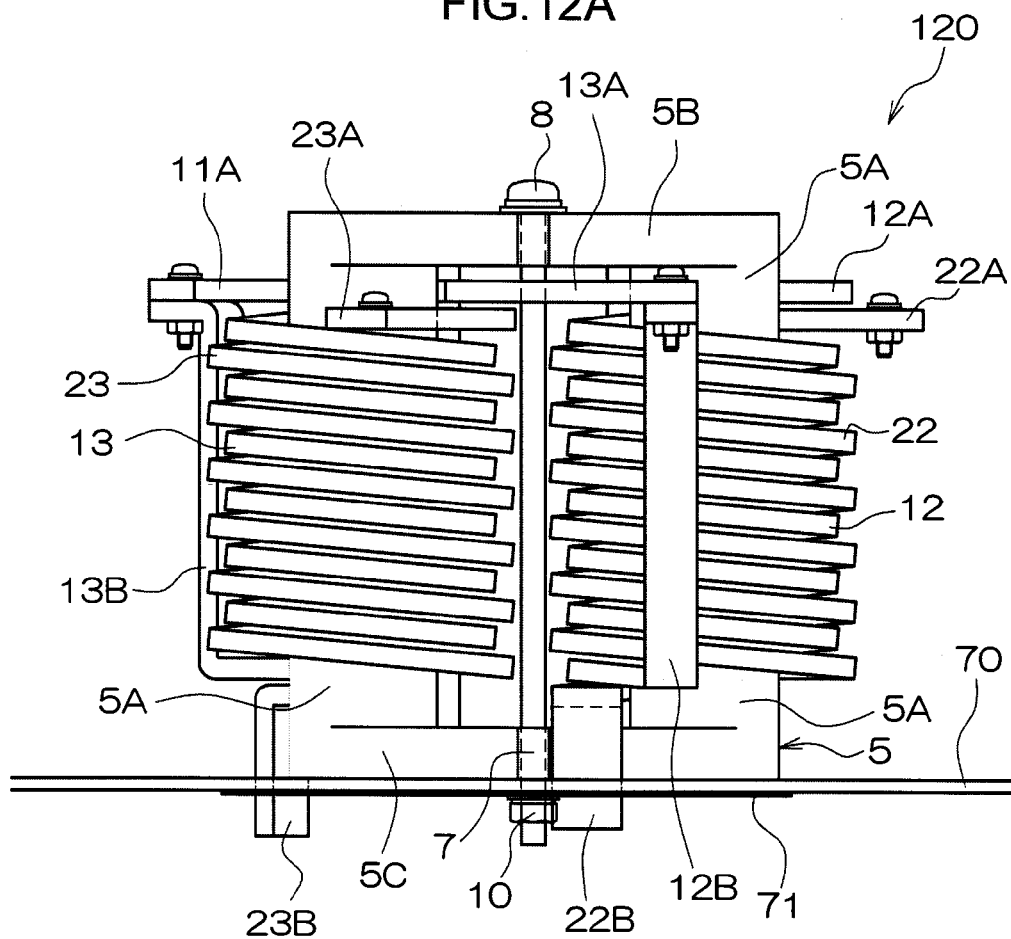




FIG. 12B

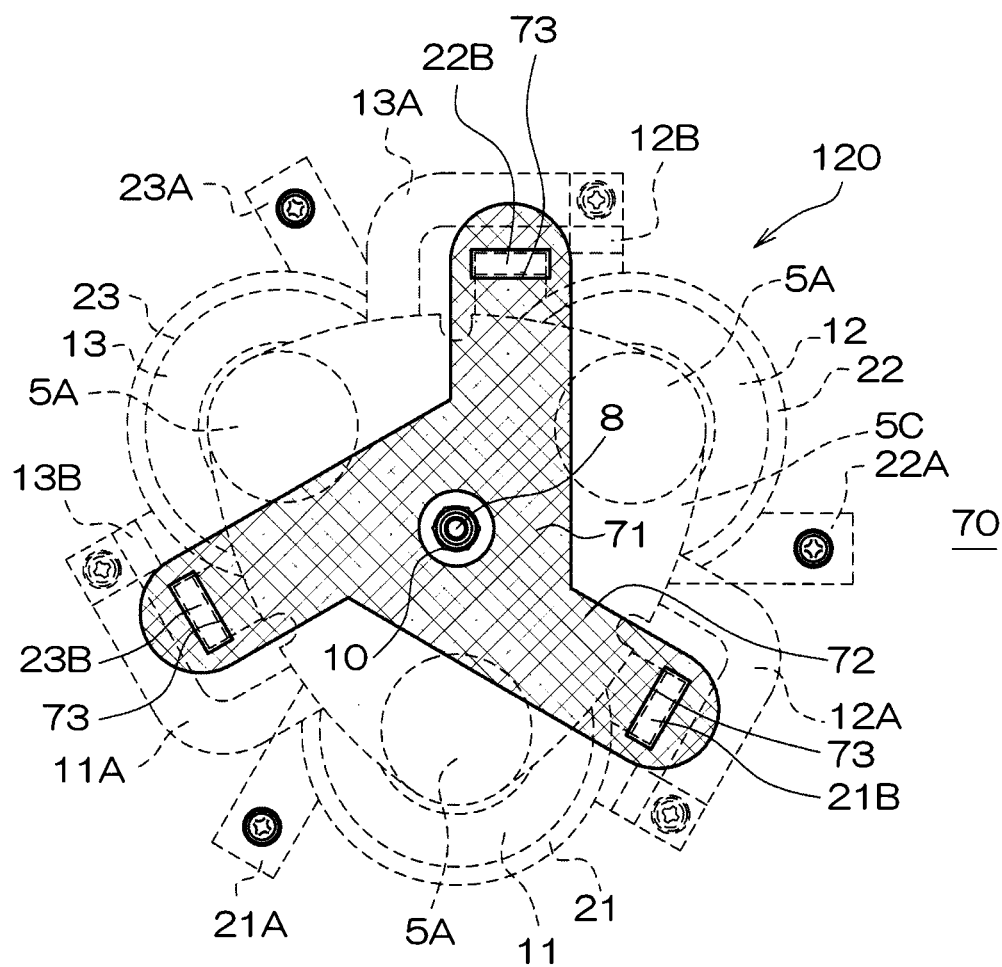


FIG.13A

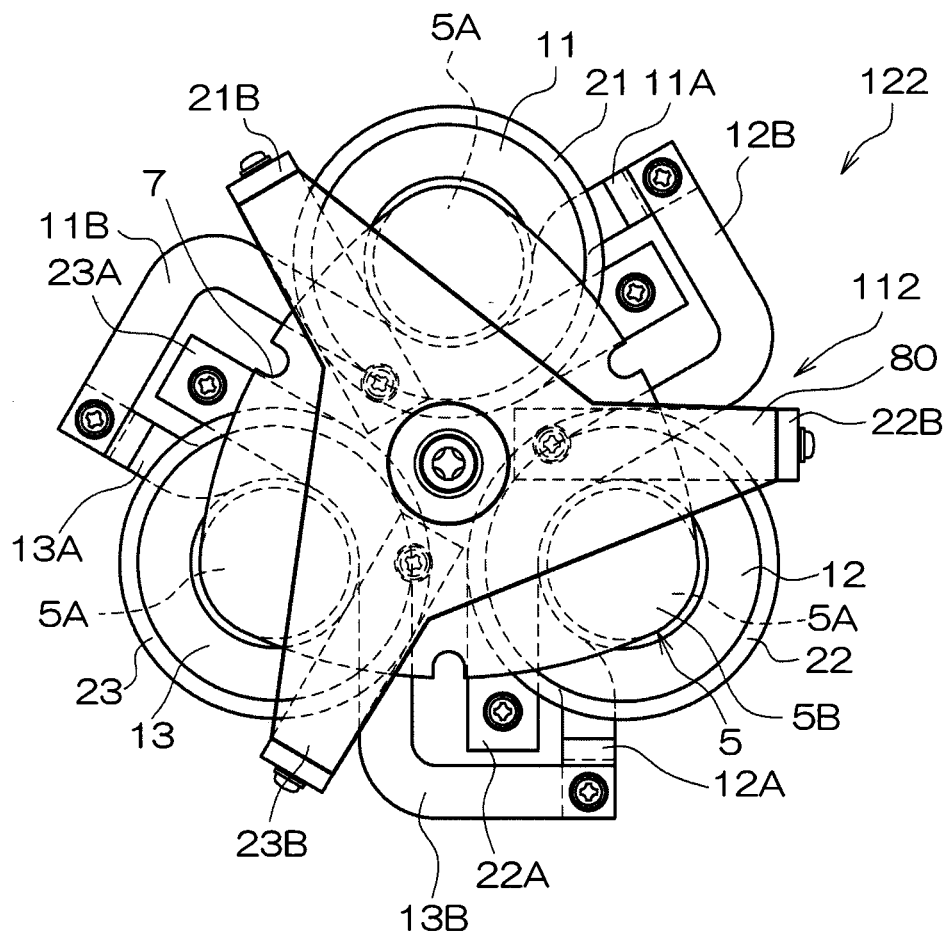


FIG.13B

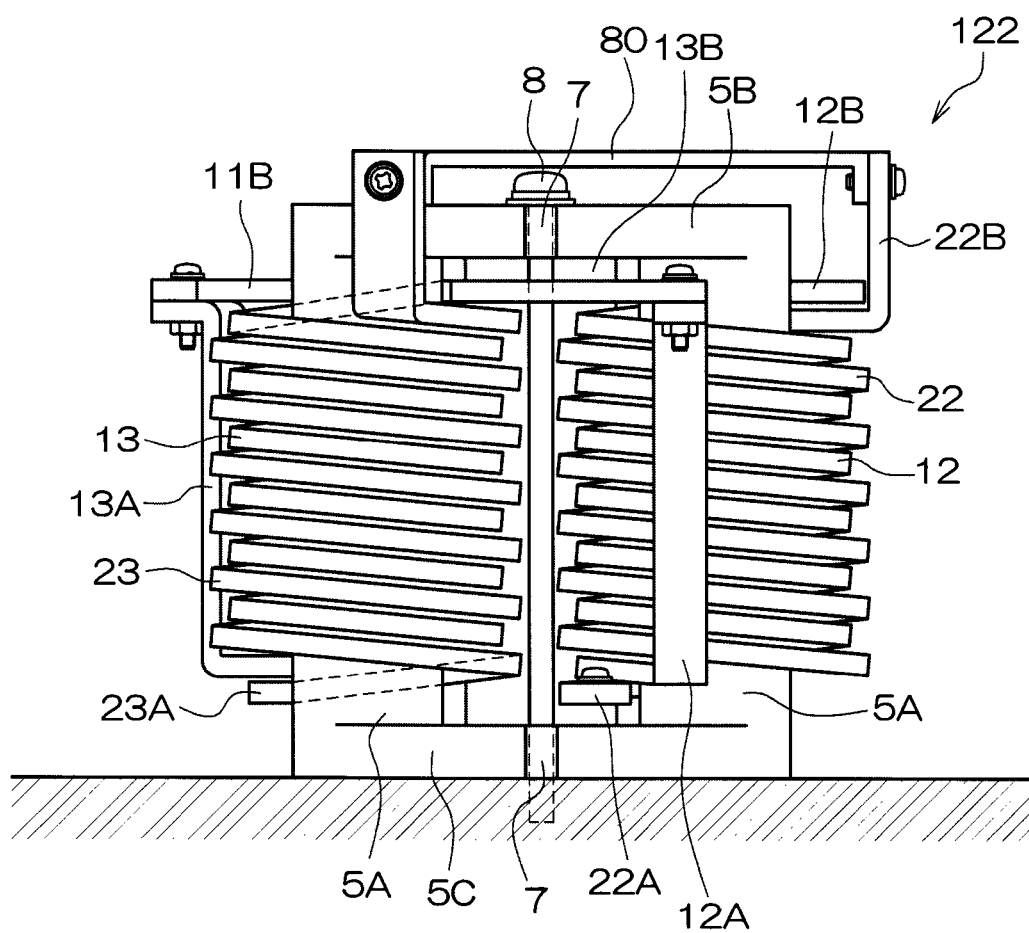


FIG.14A

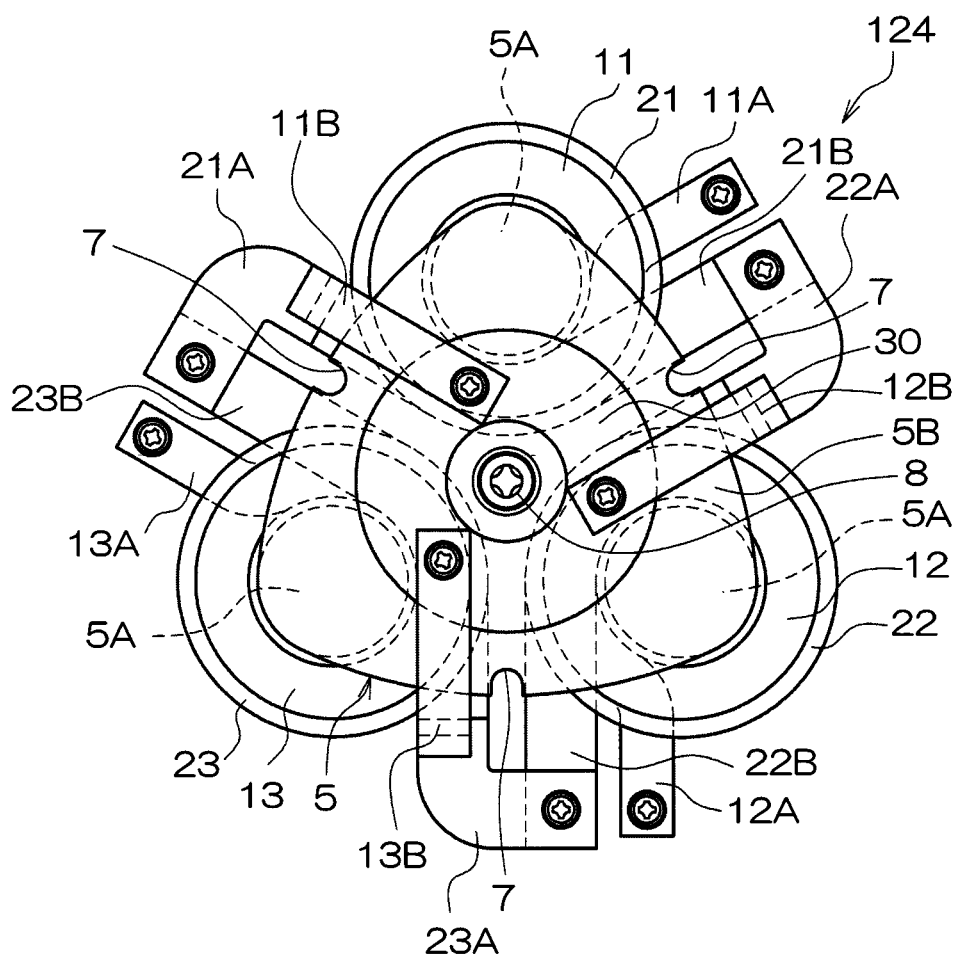


FIG.14B

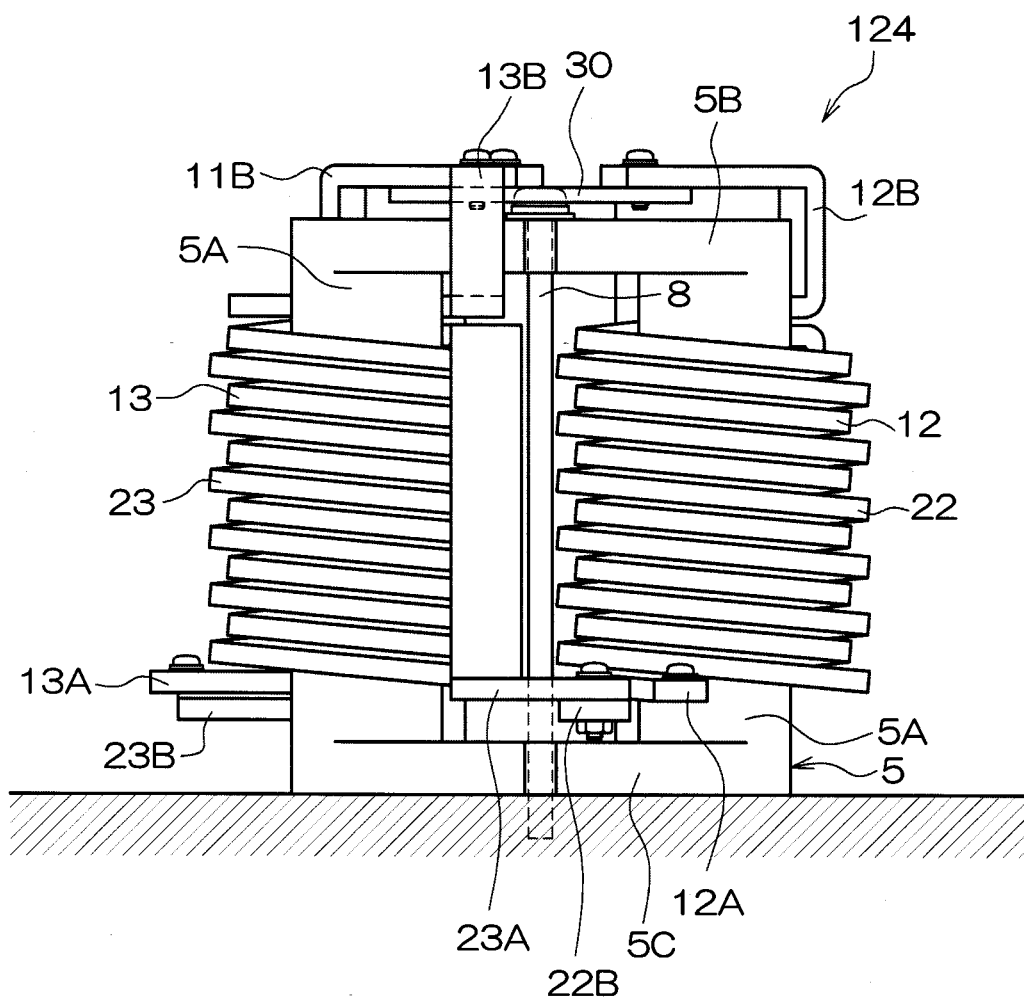


FIG.15A

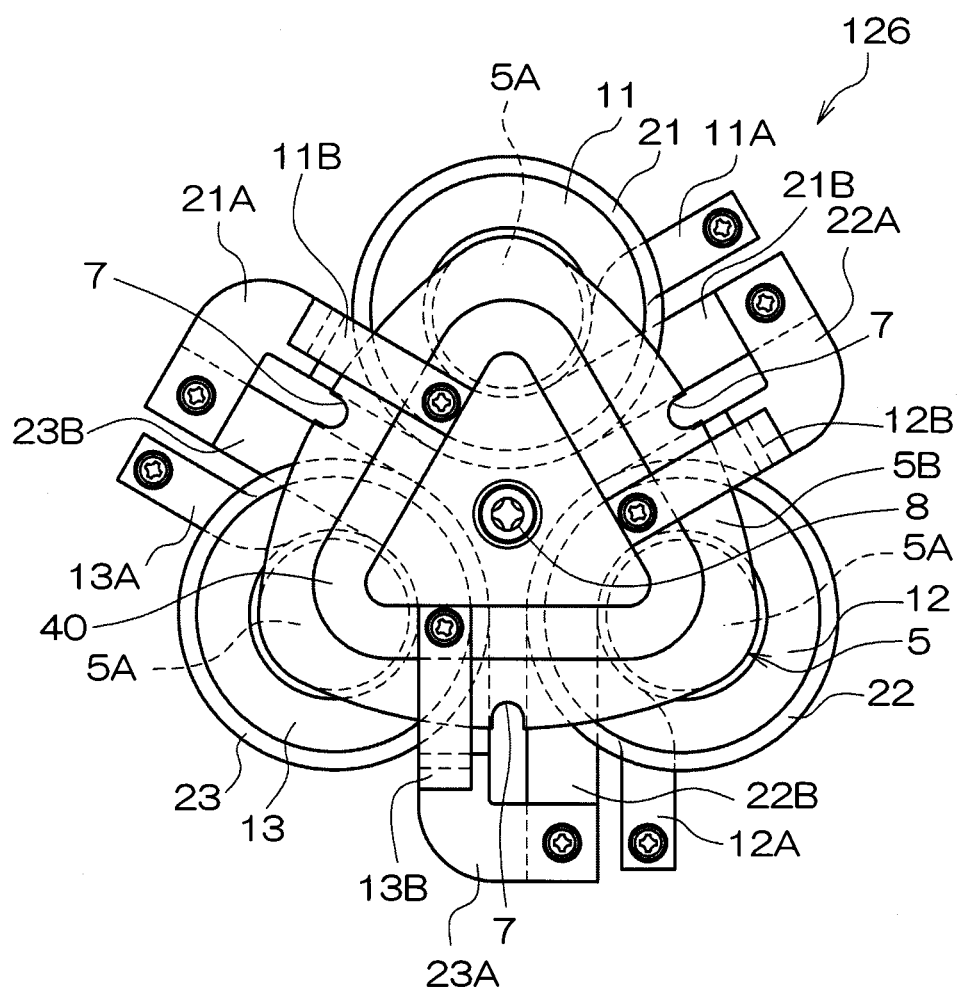


FIG. 15B

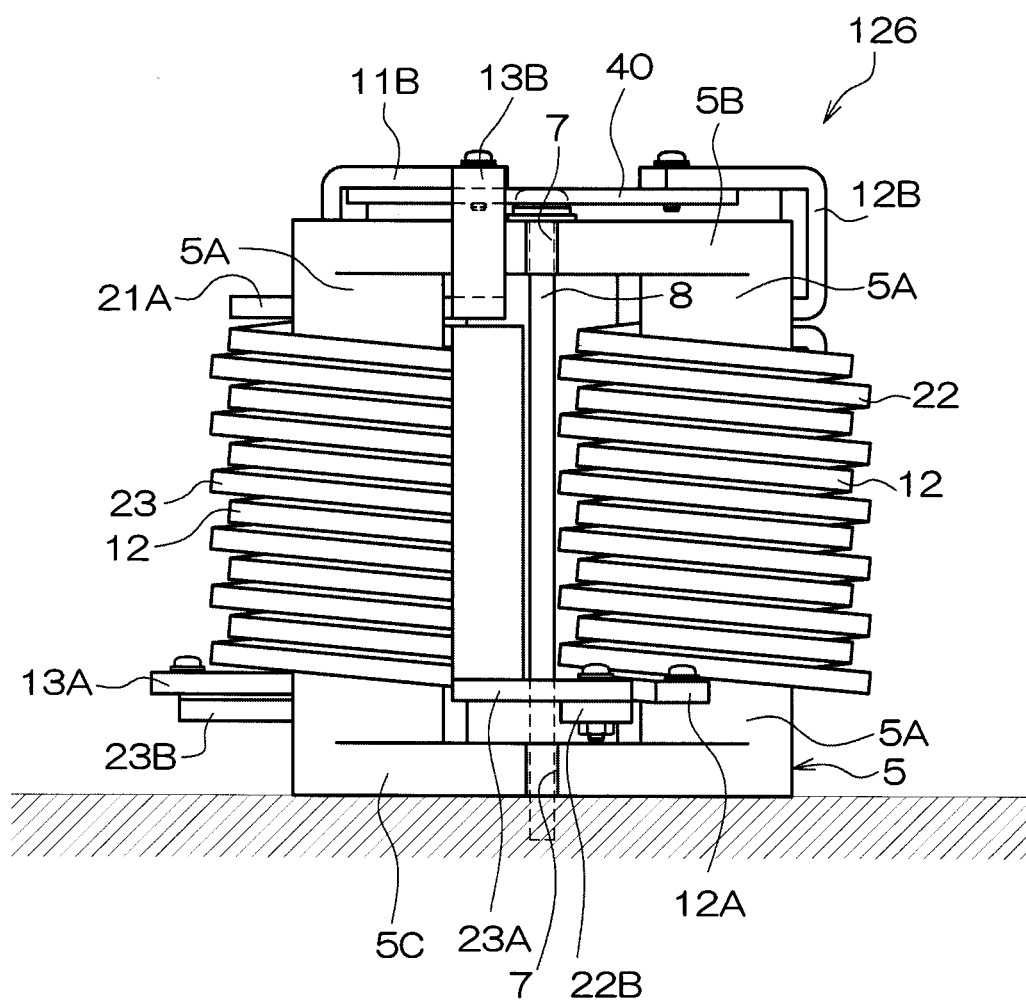


FIG.16A

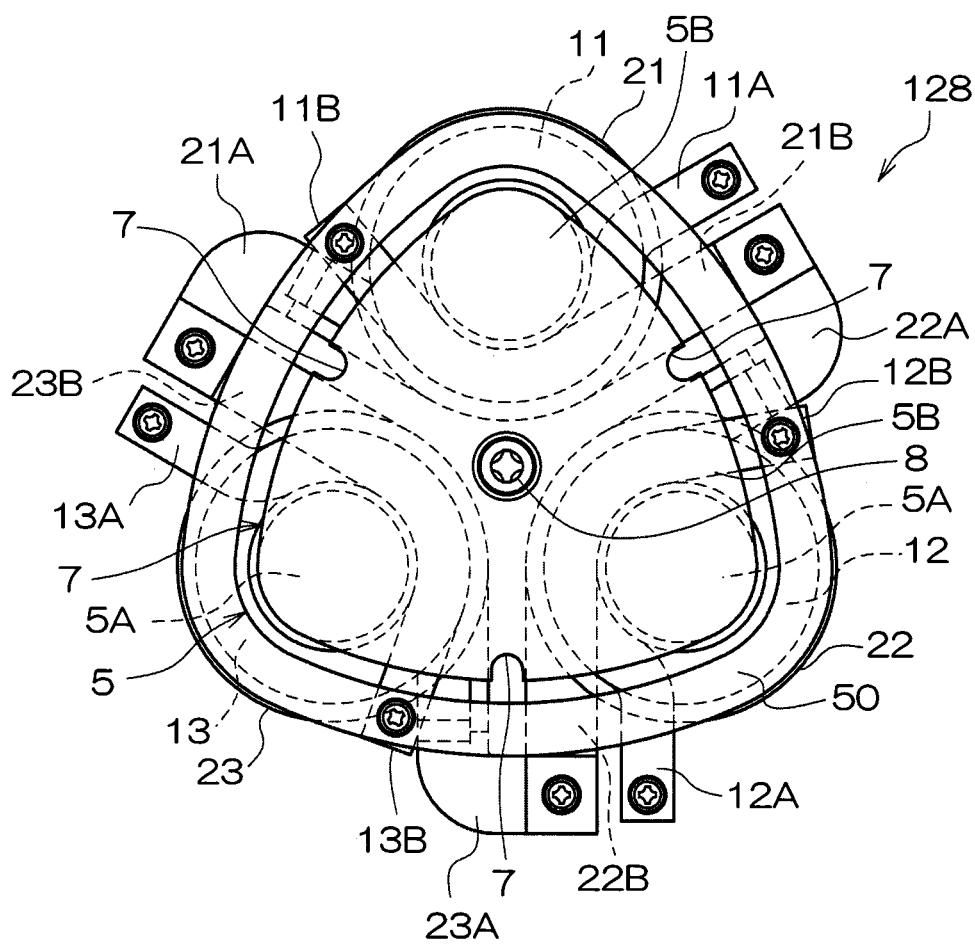




FIG.16B

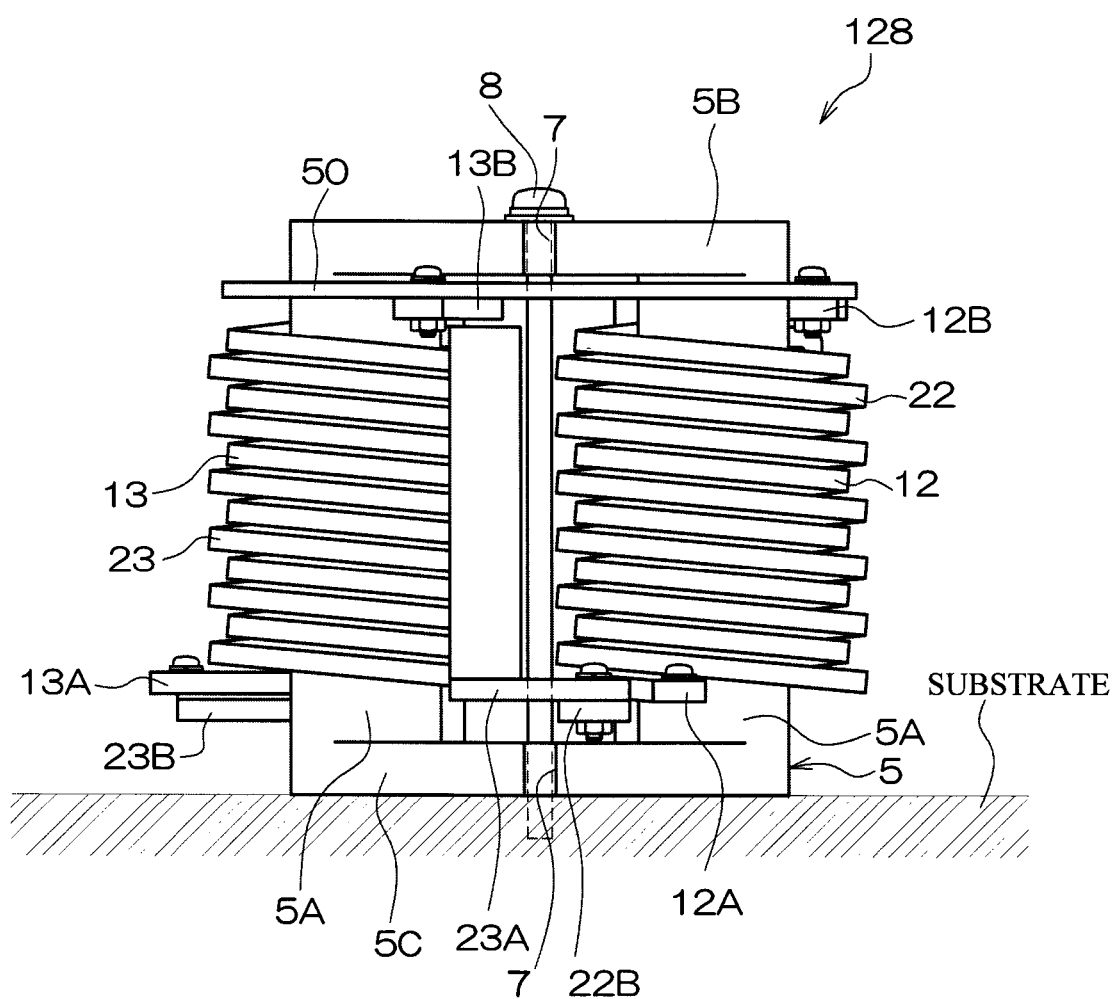


FIG. 17A

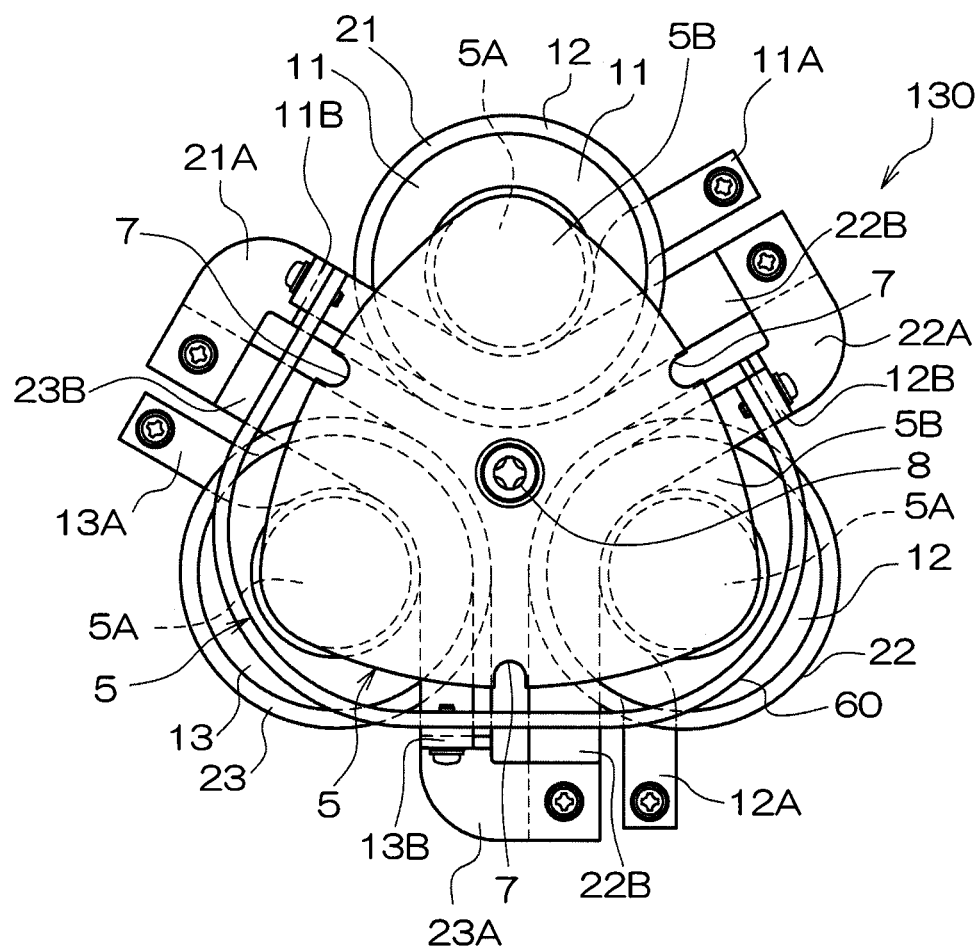


FIG.17B

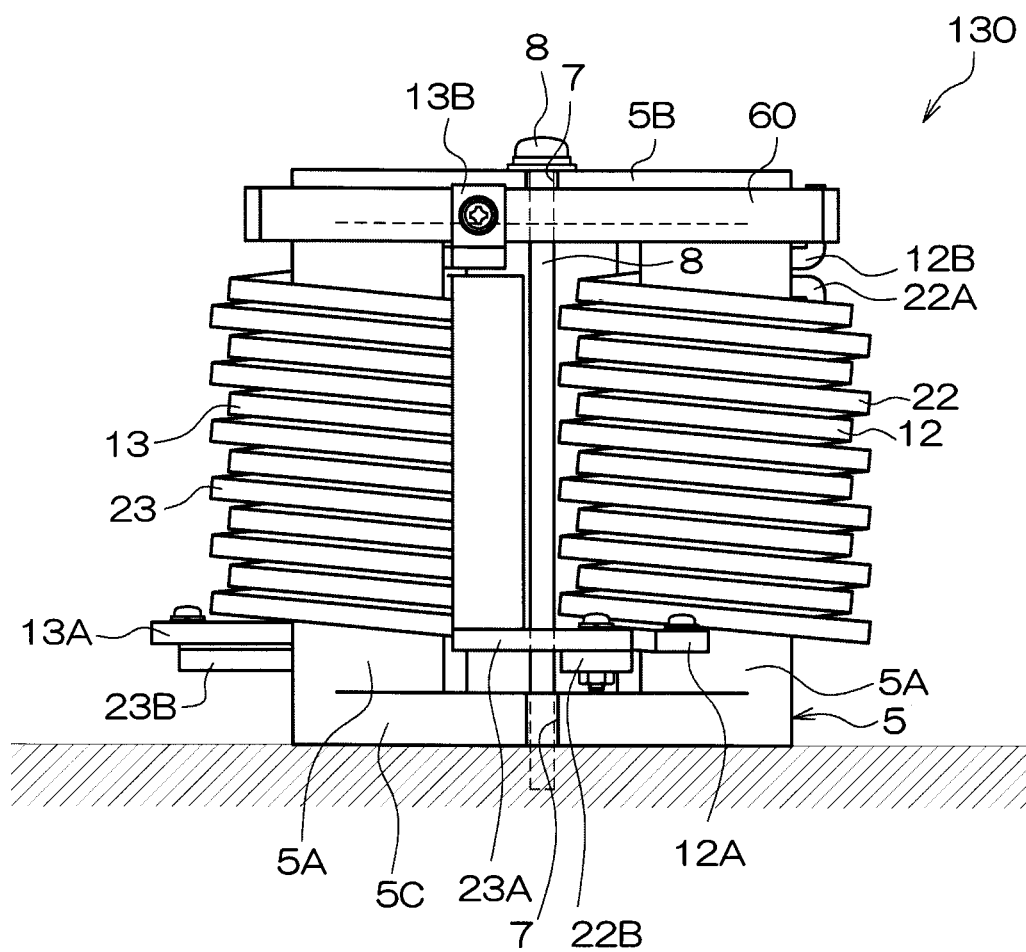


FIG. 18A

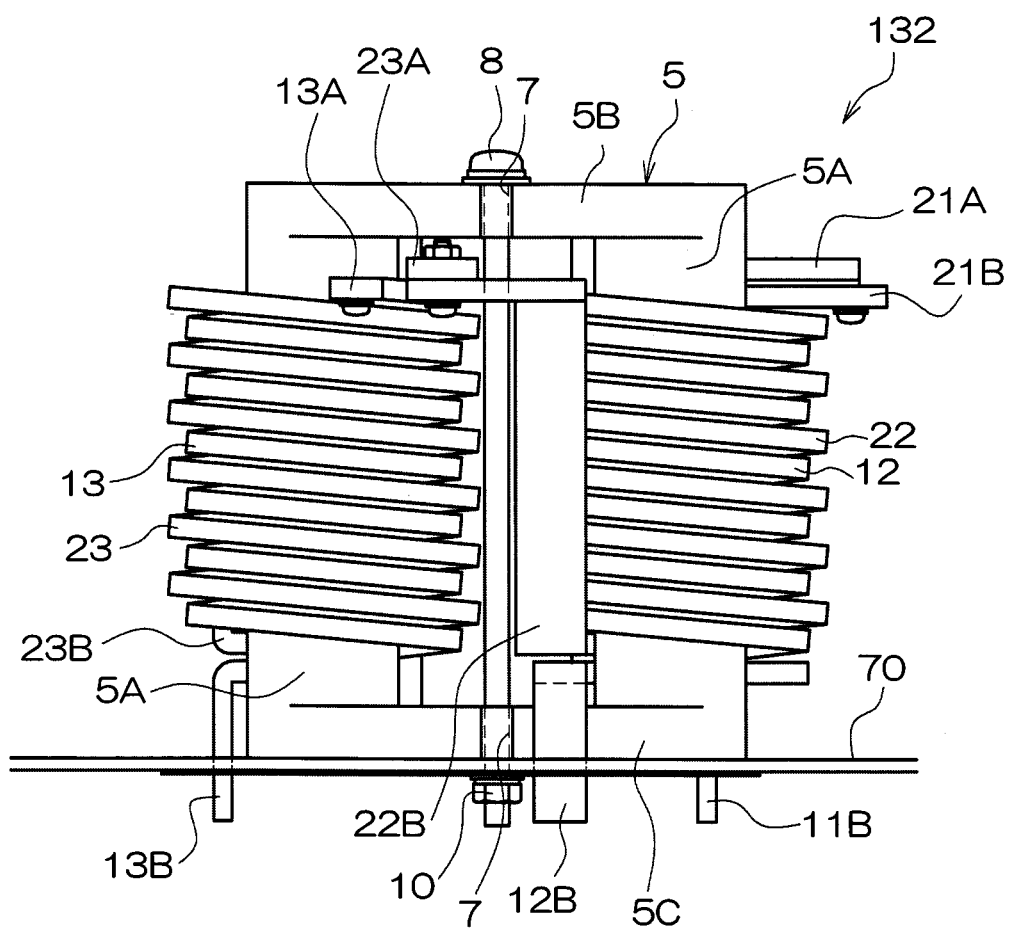


FIG. 18B

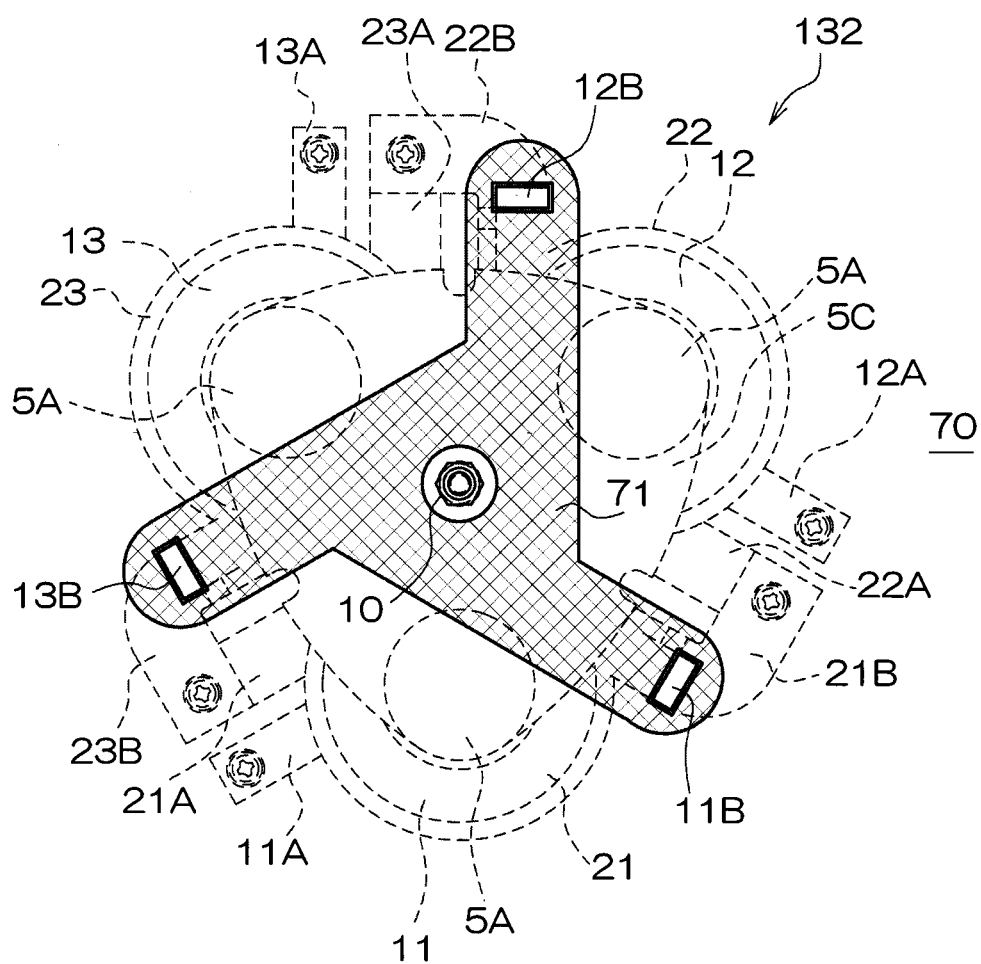


FIG. 19A

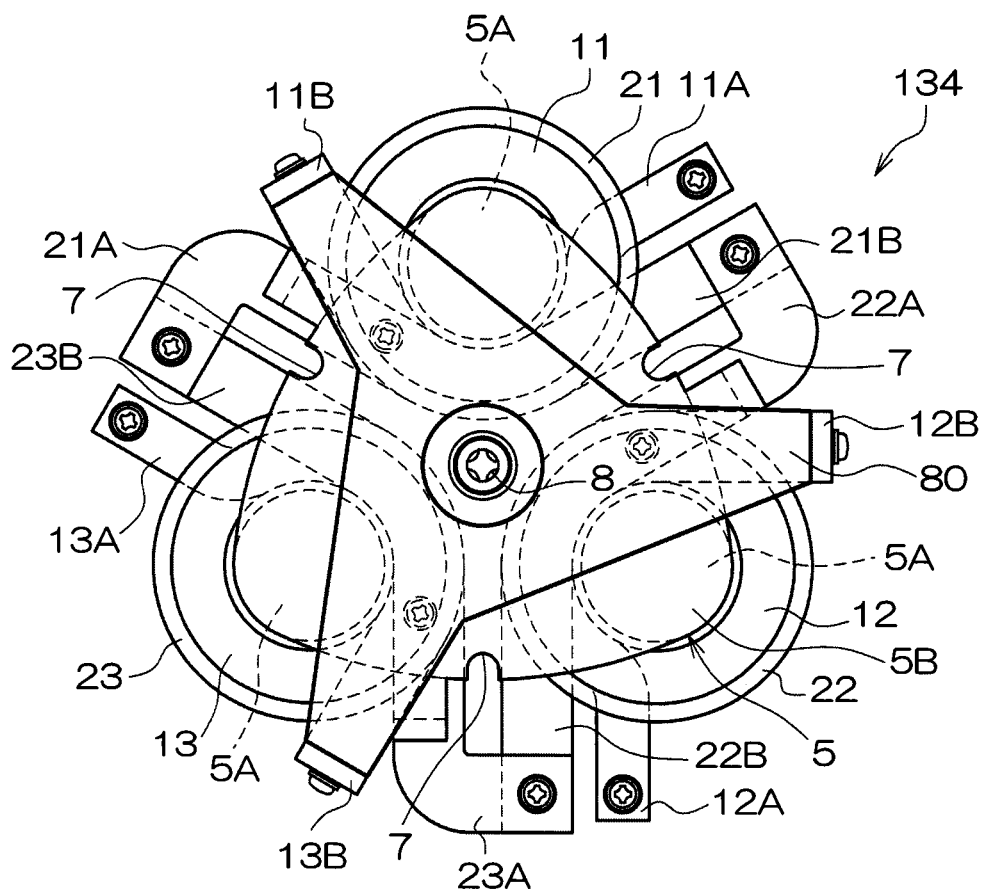
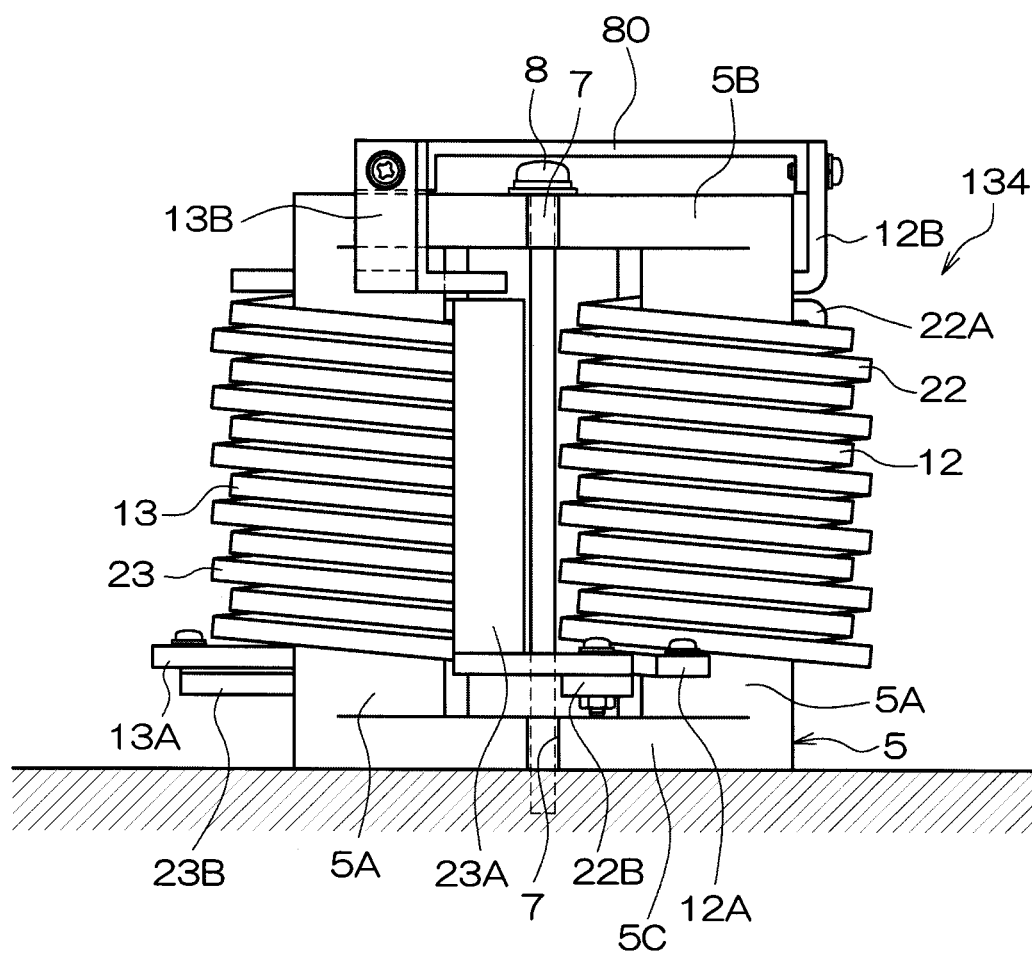


FIG.19B



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# THREE-PHASE HIGH FREQUENCY TRANSFORMER

## RELATED APPLICATIONS

This application is a National Stage Application under 35 U.S.C. 371 of co-pending PCT application PCT/JP2009/064448 designating the United States and filed Aug. 18, 2009; which claims the benefit of JP patent application number 2009-092395 and filed Apr. 6, 2009 and JP patent application number 2008-214993 and filed Aug. 25, 2008 all of which are hereby incorporated by reference in their entireties.

## TECHNICAL FIELD

The present invention relates to a three-phase high frequency transformer, and in particular, to a three-phase high frequency transformer that is suitable for use in an electric power converter and for use in an electric power source device.

## BACKGROUND TECHNOLOGY

A triangularly-arranged three-legged core type three-phase transformer is proposed in which three iron cores, in which unit blocks, whose lateral cross-section is parallelogram-shaped and in which magnetic steel plates of a predetermined width are laminated, are set face-to-face with one another and are joined at 60° angles and the outer tangent line thereof is substantially circular, are arranged at the vertices of an equilateral triangle and are made to stand side-by-side with respect to one another, and upper and lower ends of these three iron cores are respectively joined by yokes (Japanese Patent Application Laid-Open No. 9-232164).

## DISCLOSURE OF THE INVENTION

### Problems to be Solved by the Invention

However, in a high frequency transformer that is used in an electric power converter or an electric power source device, in order to prevent magnetic flux leakage, alternately winding primary coils and secondary coils is generally carried out, such as winding the secondary coils so as to be enveloped by the primary coils, or so-called sandwich winding that, after winding the primary coil, winding the secondary coil, and further winding a primary coil thereon.

However, when adopting the above-described structure, the coupling degree is low and the leakage inductance is high. Therefore, there is the problem that the voltage ratio of the secondary output voltage is not in accordance with the turns ratio of the primary coils and the secondary coils, and the secondary output voltage drops when load current flows.

Further, in the high frequency transformer of the above-described structure, the primary coils and the secondary coils are wound in a superposed manner, and in addition, insulating materials are inserted between the primary coils and the secondary coils. Therefore, there is also the problem that heat is confined, and the current density at the primary coils and the secondary coils decreases.

The present invention was made in order to overcome the above-described problems, and an object thereof is to provide a high frequency transformer in which, because the voltage ratio of the secondary output voltage is in accordance with the turns ratio of the primary coils and the

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secondary coils, a drop in the secondary output voltage when load current flows is prevented, and further, heat being confined between the primary coils and the secondary coils can be prevented, and that is suitable for use in an electric power converter and an electric power source device.

### Means for Solving the Problems

The invention of claim 1 relates to a three-phase high frequency transformer having: three solid-cylindrical cores that are formed of ferrite and that are disposed at uniform intervals on a circumference; a ceiling plate that is formed of ferrite and that connects one ends of the solid-cylindrical cores; a bottom plate that is formed of ferrite and that connects other ends of the solid-cylindrical cores; and three sets of coils having primary coils of a predetermined inner diameter that are formed by bending flat wires a plurality of times in width directions of the flat wires, and secondary coils that are formed such that an inner diameter is the same as the inner diameter of the primary coils by bending flat wires, that have a width that is different than a width of the flat wires, in width directions of the flat wires, and within intervals of the flat wires that structure ones of the primary coils and the secondary coils the flat wires that structure others of the primary coils and the secondary coils are interposed, and the three sets of coils are structured such that inner peripheries of the primary coils and inner peripheries of the secondary coils coincide, and are disposed such that the respective solid-cylindrical cores are inserted in respective inner portions, wherein a ceiling plate-side one end of any primary coil of the coils and a bottom plate-side other end of another one primary coil are connected, and a ceiling plate-side one end of the other one primary coil and a bottom plate-side other end of yet another one primary coil are connected, and a ceiling plate-side one end of the yet another one primary coil and a bottom plate-side other end of the any primary coil are connected, and a ceiling plate-side one end of any secondary coil of the coils and a bottom plate-side other end of another one secondary coil are connected, and a ceiling plate-side one end of the other one secondary coil and a bottom plate-side other end of yet another one secondary coil are connected, and a ceiling plate-side one end of the yet another one secondary coil and a bottom plate-side other end of the any secondary coil are connected.

The invention of claim 2 relates to a three-phase high frequency transformer having: three solid-cylindrical cores that are formed of ferrite and that are disposed at uniform intervals on a circumference; a ceiling plate that is formed of ferrite and that connects one ends of the solid-cylindrical cores; a bottom plate that is formed of ferrite and that connects other ends of the solid-cylindrical cores; and three sets of coils having primary coils of a predetermined inner diameter that are formed by bending flat wires a plurality of times in width directions of the flat wires, and secondary coils that are formed such that an inner diameter is the same as the inner diameter of the primary coils by bending flat wires, that have a width that is different than a width of the flat wires, in width directions of the flat wires, and within intervals of the flat wires that structure ones of the primary coils and the secondary coils the flat wires that structure others of the primary coils and the secondary coils are interposed, and the three sets of coils are structured such that inner peripheries of the primary coils and inner peripheries of the secondary coils coincide, and are disposed such that the respective solid-cylindrical cores are inserted in respective inner portions, wherein one ends at ceiling plate-sides or bottom plate-sides of the primary coils among the coils are



connected to one another, and one ends at ceiling plate-sides or bottom plate-sides of the secondary coils are connected to one another.

The invention recited in claim 3 relates to a three-phase high frequency transformer having: three solid-cylindrical cores that are formed of ferrite and that are disposed at uniform intervals on a circumference; a ceiling plate that is formed of ferrite and that connects one ends of the solid-cylindrical cores; a bottom plate that is formed of ferrite and that connects other ends of the solid-cylindrical cores; and three sets of coils having primary coils of a predetermined inner diameter that are formed by bending flat wires a plurality of times in width directions of the flat wires, and secondary coils that are formed such that an inner diameter is the same as the inner diameter of the primary coils by bending flat wires, that have a width that is different than a width of the flat wires, in width directions of the flat wires, and within intervals of the flat wires that structure ones of the primary coils and the secondary coils the flat wires that structure others of the primary coils and the secondary coils are interposed, and the three sets of coils are structured such that inner peripheries of the primary coils and inner peripheries of the secondary coils coincide, and are disposed such that the respective solid-cylindrical cores are inserted in respective inner portions, wherein a ceiling plate-side one end of any primary coil of the coils and a bottom plate-side other end of another one primary coil are connected, and a ceiling plate-side one end of the other one primary coil and a bottom plate-side other end of yet another one primary coil are connected, and a ceiling plate-side one end of the yet another one primary coil and a bottom plate-side other end of the any primary coil are connected, and one ends at ceiling plate-sides or bottom plate-sides of the secondary coils at the coils are connected to one another.

The invention of claim 4 relates to a three-phase high frequency transformer having: three solid-cylindrical cores that are formed of ferrite and that are disposed at uniform intervals on a circumference; a ceiling plate that is formed of ferrite and that connects one ends of the solid-cylindrical cores; a bottom plate that is formed of ferrite and that connects other ends of the solid-cylindrical cores; and three sets of coils having primary coils of a predetermined inner diameter that are formed by bending flat wires a plurality of times in width directions of the flat wires, and secondary coils that are formed such that an inner diameter is the same as the inner diameter of the primary coils by bending flat wires, that have a width that is different than a width of the flat wires, in width directions of the flat wires, and within intervals of the flat wires that structure ones of the primary coils and the secondary coils the flat wires that structure others of the primary coils and the secondary coils are interposed, and the three sets of coils are structured such that inner peripheries of the primary coils and inner peripheries of the secondary coils coincide, and are disposed such that the respective solid-cylindrical cores are inserted in respective inner portions, wherein one ends at ceiling plate-sides or bottom plate-sides of the primary coils at the coils are connected to one another, and a ceiling plate-side one end of any secondary coil of the coils and a bottom plate-side other end of another one secondary coil are connected, and a ceiling plate-side one end of the other one secondary coil and a bottom plate-side other end of yet another one secondary coil are connected, and a ceiling plate-side one end of the yet another one secondary coil and a bottom plate-side other end of the any secondary coil are connected.

#### Effects of the Invention

In the three-phase high frequency transformer recited in claim 1, because both the primary coils and the secondary

coils are  $\Delta$ -connected, the respective interphase currents are  $1/\sqrt{3}$  with respect to the voltage between the primary lines and the voltage between the secondary lines, and the windings of the primary coils and the secondary coils that are respectively wound around the three solid-cylindrical cores can be made narrow, and therefore, the three-phase high frequency transformer is suitable for large current use.

In the three-phase high frequency transformer recited in claim 2, because both the primary coils and the secondary coils are Y-connected, the respective interphase voltages are  $1/\sqrt{3}$  with respect to the voltage between the primary lines and the voltage between the secondary lines, and the numbers of turns of the primary coils and the secondary coils that are respectively wound around the three solid-cylindrical cores also are  $1/\sqrt{3}$ , and therefore, the three-phase high frequency transformer can be constituted compactly and large electric power can be handled.

In the three-phase high frequency transformer recited in claim 3, because the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected, the three-phase high frequency transformer is suitable as a transformer for step-up. Further, there is also the advantage that, when high frequency waves are included in the input, the high frequency waves circulate through the primary coils that are  $\Delta$ -connected, and therefore, the high frequency waves do not mix with the output waves.

In the three-phase high frequency transformer recited in claim 4, because the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected, the output of the secondary coils is suitable as a transformer for low voltage and large current. Further, in the same way as the three-phase high frequency transformer recited in claim 3, there is also the advantage that, when high frequency waves are included in the input, the high frequency waves circulate through the secondary coils that are  $\Delta$ -connected, and therefore, the high frequency waves do not mix with the output waves.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 1.

FIG. 1B is a side view showing the structure when viewing the three-phase high frequency transformer relating to embodiment 1 from the direction of arrow A in FIG. 1A.

FIG. 1C is a side view showing the structure when viewing the three-phase high frequency transformer relating to embodiment 1 from the direction of arrow B in FIG. 1A.

FIG. 1D is a side view showing the structure when viewing the three-phase high frequency transformer relating to embodiment 1 from the direction of arrow C in FIG. 1A.

FIG. 2A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 2.

FIG. 2B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 2.

FIG. 2C is a bottom view showing the structure of the three-phase high frequency transformer relating to embodiment 2.

FIG. 3A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 3.

FIG. 3B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 3.

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FIG. 3C is a bottom view showing the structure of the three-phase high frequency transformer relating to embodiment 3.

FIG. 4A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 4.

FIG. 4B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 4.

FIG. 4C is a bottom view showing the structure of the three-phase high frequency transformer relating to embodiment 4.

FIG. 5A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 5.

FIG. 5B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 5.

FIG. 5C is a bottom view showing the structure of the three-phase high frequency transformer relating to embodiment 5.

FIG. 6A is a side view showing the structure of a three-phase high frequency transformer relating to embodiment 6.

FIG. 6B is a bottom view when viewing the three-phase high frequency transformer relating to embodiment 6 from the reverse side of a printed substrate.

FIG. 7A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 7.

FIG. 7B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 7.

FIG. 7C is a bottom view showing the structure of the three-phase high frequency transformer relating to embodiment 7.

FIG. 8A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 8.

FIG. 8B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 8.

FIG. 9A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 9.

FIG. 9B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 9.

FIG. 10A is a bottom view showing the structure of a three-phase high frequency transformer relating to embodiment 10.

FIG. 10B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 10.

FIG. 11A is a bottom view showing the structure of a three-phase high frequency transformer relating to embodiment 11.

FIG. 11B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 11.

FIG. 12A is a side view showing the structure of a three-phase high frequency transformer relating to embodiment 12.

FIG. 12B is a bottom view when viewing the three-phase high frequency transformer relating to embodiment 12 from the reverse side of a printed substrate.

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FIG. 13A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 13.

FIG. 13B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 13.

FIG. 14A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 14.

FIG. 14B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 14.

FIG. 15A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 15.

FIG. 15B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 15.

FIG. 16A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 16.

FIG. 16B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 16.

FIG. 17A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 17.

FIG. 17B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 17.

FIG. 18A is a side view showing the structure of a three-phase high frequency transformer relating to embodiment 18.

FIG. 18B is a bottom view when viewing the three-phase high frequency transformer relating to embodiment 18 from the reverse side of a printed substrate.

FIG. 19A is a plan view showing the structure of a three-phase high frequency transformer relating to embodiment 19.

FIG. 19B is a side view showing the structure of the three-phase high frequency transformer relating to embodiment 19.

## FORMS FOR EMBODYING THE INVENTION

### 1. Embodiment 1

Of the three-phase high frequency transformers of the present invention, an example in which both the primary coils and the secondary coils are  $\Delta$ -connected is described hereinafter.

As shown in FIG. 1A to FIG. 1D, in a three-phase high frequency transformer 10 relating to embodiment 1, primary coils 11, 12, 13 and secondary coils 21, 22, 23 are wound at a three-legged ferrite core 5 for three phases.

The three-legged ferrite core 5 is comprehended as the ferrite cores of the high frequency transformer of the present invention, and, as shown in FIG. 1A to FIG. 1D, has three columnar cores 5A that are formed from ferrite and are disposed on a circumference at intervals of  $120^\circ$ , a ceiling plate 5B that is plate-shaped and is formed of ferrite and connects the upper ends of the three columnar cores 5A, and a bottom plate 5C that is formed of ferrite and connects the lower ends of the three columnar cores 5A.

The ceiling plate 5B and the bottom plate 5C have planar configurations that are shaped as equilateral triangles in which the vertices are rounded and each side swells in an arc

shape toward the outer side. Further, a bolt insert-through hole 6 for the inserting-through of a fixing bolt (not shown) is provided in the central portion, and a bolt insert-through groove 7 similarly for the inserting-through of a fixing bolt is provided at the central portion of each side.

At the three-legged ferrite core 5, the columnar cores 5A can be divided upward and downward in two along a plane that is orthogonal to the axes thereof, and the upper halves can be made integral with the ceiling plate 5B, and the lower halves can be made integral with the bottom plate 5C. Further, instead of dividing the columnar cores 5A in two upward and downward, the columnar cores 5A and one of the ceiling plate 5B and the bottom plate 5C may be formed integrally, and the other of the ceiling plate 5B and the bottom plate 5C may be formed so as to be able to be separated from the columnar cores 5A.

The primary coil 11 and the secondary coil 21 are wound around one of the three columnar cores 5A, the primary coil 12 and the secondary coil 22 are wound around another one, and the primary coil 13 and the secondary coil 23 are wound around yet another one.

In other words, the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 that structure the respective coils are coils that are formed by bending flat wires along the width directions thereof into annular shapes whose inner diameters are the same. Flat wires of different widths are used, and the flat wires that structure the secondary coils 21, 22, 23 are positioned within the intervals of the flat wires that structure the primary coils 11, 12, 13, and are disposed such that the inner peripheries thereof coincide.

Next, the connection of the primary coils together and the secondary coils together in the above-described three groups of coils is described by using FIG. 1A to FIG. 1D. FIG. 1A is a plan view when viewing the three-phase high frequency transformer 10 from above, FIG. 1B is a side view when viewing the three-phase high frequency transformer 10 from the direction of arrow A in FIG. 1A, FIG. 1C is a side view when viewing from the direction of arrow B in FIG. 1A, and FIG. 1D is a side view when viewing from the direction of arrow C in FIG. 1A.

As shown in FIG. 1A to FIG. 1D, at the three-phase high frequency transformer 10, both the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 are wound around from the lower ends of the columnar cores 5A toward the upper ends. The winding start portion and the winding end portion of the primary coil 11 are respectively made to be lead lines 11A, 11B. Similarly, the winding start portion and the winding end portion of the primary coil 12 are respectively made to be lead lines 12A, 12B, and the winding start portion and the winding end portion of the primary coil 13 are respectively made to be lead lines 13A, 13B. Similarly, the winding start portion and the winding end portion of the secondary coil 21 are respectively made to be lead lines 21A, 21B, and the winding start portion and the winding end portion of the secondary coil 22 are respectively made to be lead lines 22A, 22B, and the winding start portion and the winding end portion of the secondary coil 23 are respectively made to be lead lines 23A, 23B.

With regard to the primary coils 11, 12, 13, as shown in FIG. 1A and FIG. 1B, the lead line 11B of the winding end portion of the primary coil 11 is connected by a bolt to the upper end of a connection line 14A in the vertical direction, and the lower end of the connection line 14A is bent in the horizontal direction and is made to be the lead line 12A of the winding start portion of the primary coil 12. Similarly, as shown in FIG. 1A and FIG. 1C, the lead line 12B of the winding end portion of the primary coil 12 is fixed by a bolt

to the upper end of a connection line 14B in the vertical direction, and the lower end of the connection line 14B is bent in the horizontal direction and is made to be the lead line 13A of the winding start portion of the primary coil 13. Further, as shown in FIG. 1A and FIG. 1D, the lead line 13B of the winding end portion of the primary coil 13 is fixed by a bolt to the upper end of a connection line 14C in the vertical direction, and the lower end of the connection line 14C is bent in the horizontal direction and is made to be the lead line 11A of the winding start portion of the primary coil 11.

On the other hand, with regard to the secondary coils 21, 22, 23, as shown in FIG. 1A and FIG. 1B, the lead line 21B of the winding end portion of the secondary coil 21 is bent downward and made to be a connection line 15A, and the lower end of the connection line 15A is bent in the horizontal direction and fixed by a bolt to the lead line 22A of the winding start of the secondary coil 22. Similarly, as shown in FIG. 1A and FIG. 1C, the lead line 22B of the winding end portion of the secondary coil 22 is bent downward and made to be a connection line 15B, and the lower end of the connection line 15B is bent in the horizontal direction and fixed by a bolt to the lead line 23A of the winding start of the secondary coil 23. Moreover, as shown in FIG. 1A and FIG. 1D, the lead line 23B of the winding end portion of the secondary coil 23 is bent downward and made to be a connection line 15C, and the lower end of the connection line 15C is bent in the horizontal direction and fixed by a bolt to the lead line 21A of the winding start of the secondary coil 21.

The U-phase, V-phase, W-phase at the input side are respectively connected to the connection lines 14A, 14B, 14C, and the U-phase, V-phase, W-phase at the output side are respectively connected to the connection lines 15A, 15B, 15C. The connection of the U-phase, V-phase, W-phase to the connection lines 14A, 14B, 14C and the connection lines 15A, 15B, 15C can be carried out at, for example, portions of bolts.

Accordingly, the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 are respectively  $\Delta$ -connected.

Operation of the three-phase high frequency transformer 10 is described hereinafter. At the three-phase high frequency transformer 10, when three-phase high frequency current of a predetermined voltage, current and frequency is applied to the connection lines 14A, 14B, 14C, due to electromagnetic induction, a three-phase high frequency current, of which voltages and currents of U-phase, V-phase, W-phase are the voltages and currents corresponding to the turns ratios of the primary coil 11 and the secondary coil 21, the primary coil 12 and the secondary coil 22, and the primary coil 13 and the secondary coil 23, is output to the connection lines 15A, 15B, 15C.

At the three-phase high frequency transformer 10, the upper half portions of the columnar cores 5A and the ceiling plate 5B, and the lower half portions of the columnar cores 5A and the bottom plate 5C are formed integrally, and respectively structure the upper half portion and the lower half portion of the three-legged ferrite core 5. Further, because the upper half portion and the lower half portion of the three-legged ferrite core 5 are strongly fastened by fixing bolts 8 that are inserted-through the bolt insert-through hole 6 and the bolt insert-through grooves 7, no air gaps are formed between the columnar cores 5A and the ceiling plate 5B and the bottom plate 5C, and between the upper half portions and the lower half portions of the columnar cores 5A, and an increase in iron loss due to the existence of air gaps can be effectively suppressed.

Further, because the inner diameters of the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** are equal, and further, the inner peripheries are disposed so as to coincide, the gaps between the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23**, and the columnar cores **5A**, are narrow, and therefore, even when used at high frequencies, a high conversion efficiency can be achieved.

Moreover, because both the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** are  $\Delta$ -connected, the current that flows to the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** is  $1/\sqrt{3}$  of the line current, and therefore, the winding conductors of the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** can be made to be thin. Accordingly, they are suited to circuits requiring large current. Further, because both the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** are  $\Delta$ -connected and structure  $\Delta$  circuits, high frequency current can be absorbed at the  $\Delta$  circuits, and there is little distortion of the magnetic flux or the induced electromotive force.

## 2. Embodiment 2

Of the three-phase high frequency transformers of the present invention, an example in which both the primary coils and the secondary coils are Y-connected is described hereinafter.

As shown in FIG. 2A to FIG. 2C, in a three-phase high frequency transformer **100** relating to embodiment 2, the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** are wound at the three-legged ferrite core **5**.

As shown in FIG. 2A to FIG. 2C, the three-legged ferrite core **5** has the three columnar cores **5A** that are formed from ferrite and are disposed on a circumference at intervals of  $120^\circ$ , the ceiling plate **5B** that is plate-shaped and formed of ferrite and connects the upper ends of the three columnar cores **5A**, and the bottom plate **5C** that is formed of ferrite and connects the lower ends of the three columnar cores **5A**.

At the three-legged ferrite core **5**, the columnar cores **5A** can be divided upward and downward in two along a plane that is orthogonal to the axes thereof, and the upper halves are made integral with the ceiling plate **5B**, and the lower halves are made integral with the bottom plate **5C**. Further, instead of dividing the columnar cores **5A** in two upward and downward, the columnar cores **5A** and one of the ceiling plate **5B** and the bottom plate **5C** may be formed integrally, and the other of the ceiling plate **5B** and the bottom plate **5C** may be formed so as to be able to be separated from the columnar cores **5A**.

The ceiling plate **5B** and the bottom plate **5C** have planar configurations that are shaped as equilateral triangles in which the vertices are rounded and each side swells in an arc shape toward the outer side. Further, the bolt insert-through hole **6** is provided in the central portion, and the fixing bolt **8** is inserted-through the bolt insert-through hole **6**. Moreover, the bolt insert-through groove **7** is provided at the central portion of each side, and the fixing bolts **8** are inserted-through the bolt insert-through grooves **7** as well. However, among the fixing bolts **8**, those that are inserted-through the bolt insert-through grooves **7** are not illustrated. Nuts **10** are screwed-together with the distal end portions of the fixing bolts **8**, and due thereto, the upper half portion and the lower half portion of the three-legged ferrite core **5** are strongly fastened.

Three leg portions **9** for fixing the three-phase high frequency transformer **100** to a substrate are provided at the bottom surface of the bottom plate **5C**.

As shown in FIG. 2A to FIG. 2C, the primary coil **11** and the secondary coil **21** are fit on one of the three columnar cores **5A**, the primary coil **12** and the secondary coil **22** are fit on another one, and the primary coil **13** and the secondary coil **23** are fit on yet another one.

The primary coil **11** and the secondary coil **21**, and the primary coil **12** and the secondary coil **22**, and the primary coil **13** and the secondary coil **23** are all formed by winding flat wires in the counterclockwise direction as seen from above, and furthermore, edgewise. Note that the winding directions of the primary coil **11** and the secondary coil **21**, and the primary coil **12** and the secondary coil **22**, and the primary coil **13** and the secondary coil **23** may be the clockwise direction as seen from above.

The primary coil **11** and the secondary coil **21** are disposed such that the flat wire that structures the secondary coil **21** is interposed in the gaps of the flat wire that structures the primary coil **11**, in other words, such that the flat wire that structures the primary coil **11** and the flat wire that structures the secondary coil **21** are lined-up alternately. Further, the number of turns of the primary coil **11** is greater than the secondary coil **21**. Accordingly, the secondary coil **21** is fit-into the central portion of the primary coil **11**, and, at the both ends of the primary coil **11**, there are portions where the secondary coil **21** is not fit-in. Accordingly, because the high frequency current that is outputted from the secondary coil **21** is larger in current and lower in voltage than the high frequency current that is inputted to the primary coil **11**, the flat wire that structures the secondary coil **21** has a thickness that is the same as but has a width that is wider than the flat wire that structures the primary coil **11**. Note that, at the secondary coil **21**, instead of using, a flat wire whose width is wider than the primary coil **11**, a flat wire whose thickness is thicker may be used. The primary coil **11** and the secondary coil **21** have equal inner diameters, and are disposed such that the inner peripheries thereof coincide. Further, the inner diameters of the primary coil **11** and the secondary coil **21** are, as compared with the outer diameter of the columnar core **5A**, large by an amount that provides a gap for insertion of an insulator.

Similarly, the primary coil **12** and the secondary coil **22** are disposed such that the flat wire that structures the secondary coil **22** is interposed in the gaps of the flat wire that structures the primary coil **12**, in other words, such that the flat wire that structures the primary coil **12** and the flat wire that structures the secondary coil **22** are lined-up alternately. Further, the number of turns of the primary coil **12** is greater than the secondary coil **22**. Accordingly, the secondary coil **22** is fit-into the central portion of the primary coil **12**, and, at the both ends of the primary coil **12**, there are portions where the secondary coil **22** is not fit-in. Accordingly, because the high frequency current that is outputted from the secondary coil **22** is larger in current and lower in voltage than the high frequency current that is inputted to the primary coil **12**, the flat wire that structures the secondary coil **22** has a thickness that is the same as but a width that is wider than the flat wire that structures the primary coil **12**. Note that, at the secondary coil **22**, instead of using a flat wire whose width is wider than the primary coil **12**, a flat wire whose thickness is thicker may be used. The primary coil **12** and the secondary coil **22** have equal inner diameters, and are disposed such that the inner peripheries thereof coincide. Further, the inner diameters of the primary coil **12** and the secondary coil **22** are, as compared with the outer diameter of the columnar core **5A**, larger by an amount that provides a gap for insertion of an insulator.

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Similarly, the primary coil 13 and the secondary coil 23 are disposed such that the flat wire that structures the secondary coil 23 is interposed in the gaps of the flat wire that structures the primary coil 13, in other words, such that the flat wire that structures the primary coil 13 and the flat wire that structures the secondary coil 23 are lined-up alternately. Further, the number of turns of the primary coil 13 is greater than the secondary coil 23. Accordingly, the secondary coil 23 is fit-into the central portion of the primary coil 13, and, at the both ends of the primary coil 13, there are portions where the secondary coil 23 is not fit-in. Accordingly, because the high frequency current that is outputted from the secondary coil 23 is large current of a lower voltage than the high frequency current that is inputted to the primary coil 13, the flat wire that structures the secondary coil 23 has a thickness that is the same as but a width that is wider than the flat wire that structures the primary coil 13. Note that, at the secondary coil 23, instead of using a flat wire whose width is wider than the primary coil 13, a flat wire whose thickness is thicker may be used. The primary coil 13 and the secondary coil 23 have equal inner diameters, and are disposed such that the inner peripheries thereof coincide. Further, the inner diameters of the primary coil 13 and the secondary coil 23 are, as compared with the outer diameter of the columnar core 5A, larger by an amount that provides a gap for insertion of an insulator.

Note that the example shown in FIG. 2A to FIG. 2C is an example of a step-down transformer, but can be made to be a step-up transformer by making the number of turns of the secondary coils 21, 22, 23 greater than the primary coils 11, 12, 13, and by making the widths of the flat wires that structure the secondary coils 21, 22, 23 more narrow than the widths of the flat wires that structure the primary coils 11, 12, 13.

The winding start portions of the primary coils 11, 12, 13 are pulled-out to the outer sides of the primary coils 11, 12, 13 and are made to be the lead lines 11A, 12A, 13A. Further, the winding end portions also are pulled-out to the outer sides of the primary coils 11, 12, 13 and are made to be the lead lines 11B, 12B, 13B.

Similarly, the winding start portions of the secondary coils 21, 22, 23 are pulled-out to the outer sides of the secondary coils 21, 22, 23 and are made to be the lead lines 21A, 22A, 23A. The winding end portions also are pulled-out to the outer sides of the secondary coils 21, 22, 23 and are made to be the lead lines 21B, 22B, 23B.

At the primary coils 11, 12, 13, the end portions of all of the lead lines 11B, 12B, 13B are bent horizontally, and are electrically connected to a connecting piece 30 that is formed from a plate-shaped conductor having a donut-shaped planar configuration. Similarly, at the secondary coils 21, 22, 23 as well, the end portions of all of the lead lines 21B, 22B, 23B are bent horizontally, and are electrically connected to a connecting piece 31 that is formed from a plate-shaped conductor having a donut-shaped planar configuration. Accordingly, both the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 are Y-connected.

On the other hand, the lead lines 11A, 12A, 13A of the primary coils 11, 12, 13 are respectively connected to the U-phase, V-phase, W-phase of the input side, and the lead lines 21A, 22A, 23A of the secondary coils 21, 22, 23 are respectively connected to the U-phase, V-phase, W-phase of the output side.

Operation of the three-phase high frequency transformer 100 is described hereinafter. At the three-phase high frequency transformer 100, when three-phase high frequency current of a predetermined voltage, current and frequency is

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applied to the lead lines 11A, 12A, 13A, due to electromagnetic induction, the U-phase, V-phase, W-phase output, to the lead lines 21A, 22A, 23A, three-phase high frequency currents that are in voltages and currents that correspond to the turns ratios of the primary coil 11 and the secondary coil 21, the primary coil 12 and the secondary coil 22, and the primary coil 13 and the secondary coil 23.

At the three-phase high frequency transformer 100, the upper half portions of the columnar cores 5A and the ceiling plate 5B, and the lower half portions of the columnar cores 5A and the bottom plate 5C, are formed integrally, and respectively structure the upper half portion and the lower half portion of the three-legged ferrite core 5. Further, because the upper half portion and the lower half portion of the three-legged ferrite core 5 are strongly fastened by the fixing bolts 8 that are inserted-through the bolt insert-through hole 6 and the bolt insert-through grooves 7, no air gaps are formed between the columnar cores 5A and the ceiling plate 5B and the bottom plate 5C, and between the upper half portions and the lower half portions of the columnar cores 5A, and an increase in iron loss due to the existence of air gaps can be effectively suppressed.

Further, because the inner diameters of the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 are equal, and further, the inner peripheries are disposed so as to coincide, the gaps between the primary coils 11, 12, 13 and the secondary coils 21, 22, 23, and the columnar cores 5A, are narrow, and therefore, even when used at high frequencies, a high conversion efficiency can be achieved.

Moreover, because both the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 are Y-connected, at both the primary coils 11, 12, 13 and the secondary coils 21, 22, 23, the respective interphase voltages are  $1/\sqrt{3}$  of the voltage between the primary lines and the voltage between the secondary lines, and the numbers of turns of the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 that are wound around the columnar cores 5A also respectively are  $1/\sqrt{3}$  and are small. Therefore, a three-phase high frequency transformer, which can be constituted compactly and furthermore by which large electric power can be handled, is provided.

## 3. Embodiment 3

Of the three-phase high frequency transformers of the present invention, a second example in which both the primary coils and the secondary coils are Y-connected is described hereinafter.

As shown in FIG. 3A to FIG. 3C, a three-phase high frequency transformer 102 relating to embodiment 3 has a similar structure as the three-phase high frequency transformer 100 of embodiment 1 except that a connecting member 40, that is formed from a plate-shaped conductor and has a triangular outer periphery whose respective vertices are rounded and in whose central portion is provided an opening portion of a similar shape as the outer periphery, is used as the connecting member that connects the lead lines 11B, 12B, 13B of the primary coils 11, 12, 13 instead of the connecting member 30 in embodiment 1, and the lead lines 21B, 22B, 23B of the secondary coils 21, 22, 23 are connected at a connecting member 41 that similarly is formed from a plate-shaped conductor and has a planar configuration that is similar to the connecting member 40. Further, the operation as well is similar.

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## 4. Embodiment 4

Of the three-phase high frequency transformers of the present invention, a third example in which both the primary coils and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **104** relating to embodiment 4, differently from the three-phase high frequency transformer **100** of embodiment 1 and the three-phase high frequency transformer **102** of embodiment 3, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** are not bent in the vertical direction and are, while still in an winding end state, connected by a connecting member **50** in a vicinity of the ceiling plate **5B** as shown in FIG. 4A to FIG. 4C. Similarly, the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** as well also are not bent in the vertical direction, and are, while still in an winding end state, connected by a connecting member **51** in a vicinity of the floor plate **5C**.

Both of the connecting members **50**, **51** are formed from plate-shaped conductors, and have triangular outer peripheries whose respective vertices are rounded, and an opening portion of a similar configuration as the outer periphery is provided in the central portions thereof. However, the connecting members **50**, **51** are positioned at the outer side of the ceiling plate **5B** or the bottom plate **5C**, respectively.

Further, the three-phase high frequency transformer **104** does not have the leg portions **9**, and instead, the bottom plate **5C** is directly placed on a substrate, and the fixing bolts **8** are screwed-together with screw holes provided in the substrate. Accordingly, the nuts **10** for fastening the upper half portion and the lower half portion of the three-legged ferrite core **5** are not needed.

In addition to the features that the three-phase high frequency transformer **100** of embodiment 1 and the three-phase high frequency transformer **102** of embodiment 3 have, the three-phase high frequency transformer **104** has the feature that the post-processing of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** and the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** can be greatly simplified, and further, has the feature that the overall structure itself also can be simplified because the nuts **10** that screw-together with the fixing bolts **8** can be omitted.

## 5. Embodiment 5

Of the three-phase high frequency transformers of the present invention, a fourth example in which both the primary coils and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **106** relating to embodiment 5, differently from the three-phase high frequency transformer **100** of embodiment 1 and the three-phase high frequency transformer **102** of embodiment 3, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** are bent upward and are connected by a connecting member **60** in a vicinity of the ceiling plate **5B** as shown in FIG. 5A to FIG. 5C. On the other hand, the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** are bent downward and are connected by a connecting member **61** in a vicinity of the floor plate **5C**.

The connecting members **60**, **61** have triangular planar shapes whose respective vertices are rounded, and are formed by bending strips that are conductors into this shape.

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The connecting members **60**, **61** are positioned at the outer side of the ceiling plate **5B** or the bottom plate **5C**, respectively.

Further, the three-phase high frequency transformer **106** does not have the leg portions **9**, and instead, the bottom plate **5C** is directly placed on a substrate, and the fixing bolts **8** are screwed-together with screw holes provided in the substrate. Accordingly, the nuts **10** for fastening the upper half portion and the lower half portion of the three-legged ferrite core **5** are not needed.

In addition to the feature that the overall structure itself also can be simplified because the nuts **10** that screw-together with the fixing bolts **8** can be omitted, the three-phase high frequency transformer **106** also has the feature that, because the connecting members **60**, **61** can be formed by bending strips that are conductors, manufacturing is easier as compared with the connecting members **50**, **51** that require punching by a press or the like.

## 6. Embodiment 6

Of the three-phase high frequency transformers of the present invention, a fifth example in which both the primary coils and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **108** relating to embodiment 6, as shown in FIG. 6A and FIG. 6B, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** and the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** are bent downward. Further, the lead lines **11B**, **12B**, **13B** are inserted in opening portions **73** that are provided in a printed circuit board **70**, and the lead lines **21B**, **22B**, **23B** are inserted in opening portions **74** that are provided in the printed circuit board **70**. Here, a connected pattern **71** is formed at the portions where the opening portions **73** are formed at the reverse (bottom surface) of the printed circuit board **70**, so as to connect the three opening portions **73**, and a connected pattern **72** is formed at the portions where the opening portions **74** are formed at the obverse (top surface) of the printed circuit board **70**, so as to connect the three opening portions **74**. Further, the lead lines **11B**, **12B**, **13B** are soldered to the connected pattern **71** at the opening portions **73**, and the lead lines **21B**, **22B**, **23B** are soldered to the connected pattern **72** at the opening portions **74**. Due thereto, the lead lines **11B**, **12B**, **13B** are connected at the connected pattern **71**, and the lead lines **21B**, **22B**, **23B** are connected at the connected pattern **72**.

Further, the fixing bolt **8** is inserted-through a hole provided in the printed circuit board **70**, and the nut **10** is screwed-together from the reverse side of the printed circuit board **70**.

At the three-phase high frequency transformer **108**, the structures and the like of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** are the same as the three-phase high frequency transformer **100** of embodiment 1.

The three-phase high frequency transformer **108** has a feature of being easily mounted on the printed circuit board **70** in addition to the feature of the three-phase high frequency transformer **100** of the first embodiment.

Note that, in the example shown in FIG. 6A and FIG. 6B, the connected pattern **71** that connects the primary coils **11**, **12**, **13** is formed at the bottom surface of the printed circuit board **70**, and the connected pattern **72** that connects the secondary coils **21**, **22**, **23** is formed at the top surface of the printed circuit board **70**, but, on the contrary, the connected

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pattern 71 may be formed at the top surface of the printed circuit board 70 and the connected pattern 72 may be formed at the bottom surface of the printed circuit board 70.

## 7. Embodiment 7

Of the three-phase high frequency transformers of the present invention, a sixth example in which both the primary coils and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer 110 relating to embodiment 7, as shown in FIG. 7A to FIG. 7C, the final ends of the lead lines 11B, 12B, 13B of the primary coils 11, 12, 13 are bent upward, and the final ends of the lead lines 21B, 22B, 23B of the secondary coils 21, 22, 23 are bent downward, and they are connected at connecting members 80, 81 that are substantially triangular. The connecting members 80, 81 are both triangular shapes whose ridge portions project-out to the outer sides. The distal ends of the ridge portions of the connecting member 80 are bent downward and are connected to the lead lines 11B, 12B, 13B, and the distal ends of the ridge portions of the connecting member 81 are bent upward and are connected to the lead lines 21B, 22B, 23B.

Other than the above-described points, the three-phase high frequency transformer 110 has the same structure as the three-phase high frequency transformer 100 of embodiment 1.

## 8. Embodiment 8

Of the three-phase high frequency transformers of the present invention, an example in which the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer 112 relating to embodiment 8, as shown in FIG. 8A and FIG. 8B, the primary coils 11, 12, 13 are all formed by winding flat wires upward from bottom to top, and the winding start portions are made to be the lead lines 11A, 12A, 13A respectively, and the winding end portions are made to be the lead lines 11B, 12B, 13B respectively.

The lead lines 11A, 12A, 13A of the winding start sides are respectively bent upward, and the final ends thereof are at substantially the same height as the lead lines 11B, 12B, 13B of the winding end sides. Further, the lead line 11B at the winding end side of the primary coil 11 is connected to the lead line 13A at the winding start side of the primary coil 13, the lead line 13B at the winding end side of the primary coil 13 is connected to the lead line 12A at the winding start side of the primary coil 12, and the lead line 12B at the winding end side of the primary coil 12 is connected to the lead line 11A at the winding start side of the primary coil 11. Further, the connected portion of the lead line 11B and the lead line 13A, the connected portion of the lead line 13B and the lead line 12A, and the connected portion of the lead line 12B and the lead line 11A are connected to the U-phase, the V-phase, the W-phase of the input side respectively. Accordingly, the primary coils 11, 12, 13 are  $\Delta$ -connected.

On the other hand, the secondary coils 21, 22, 23 are formed by winding flat wires, whose width is wider than the primary coils 11, 12, 13, upward from bottom to top, and the winding start portions are made to be the lead lines 21A, 22A, 23A respectively, and the winding end portions are made to be the lead lines 21B, 22B, 23B respectively. Note that the example shown in FIG. 8A and FIG. 8B is an example of a step-down transformer, but if it is made to be

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a step-up transformer, it suffices to use flat wires of a narrower width than the primary coils 11, 12, 13 as the secondary coils 21, 22, 23.

Further, the lead lines 21B, 22B, 23B of the winding end sides are respectively bent upward, and further, at the final end portions, are bent horizontally so as to be directed inward, and are connected to the connecting member 30. The connecting member 30 is as described in embodiment 1.

On the other hand, the lead lines 21A, 22A, 23A of the winding start sides are connected to the U-phase, the V-phase, the W-phase of the output side, respectively. Accordingly, the secondary coils 21, 22, 23 are Y-connected.

Other than the above-described points, the three-phase high frequency transformer 112 has the same structure as the three-phase high frequency transformer 100 of embodiment 1.

At the three-phase high frequency transformer 112 as well, the upper half portions of the columnar cores 5A and the ceiling plate 5B, and the lower half portions of the columnar cores 5A and the bottom plate 5C are formed integrally, and respectively structure the upper half portion and the lower half portion of the three-legged ferrite core 5. Further, because the upper half portion and the lower half portion of the three-legged ferrite core 5 are strongly fastened by the fixing bolts 8 that are inserted-through the bolt insert-through hole 6 and the bolt insert-through grooves 7, no air gaps are formed between the columnar cores 5A and the ceiling plate 5B and the bottom plate 5C, and between the upper half portions and the lower half portions of the columnar cores 5A, and therefore, an increase in iron loss due to the existence of air gaps can be effectively suppressed.

Further, because the inner diameters of the primary coils 11, 12, 13 and the secondary coils 21, 22, 23 are equal, and further, the inner peripheries are disposed so as to coincide, the gaps between the primary coils 11, 12, 13 and the secondary coils 21, 22, 23, and the columnar cores 5A, are narrow, and therefore, even when used at high frequencies, a high conversion efficiency can be achieved.

Moreover, because the primary coils 11, 12, 13 are  $\Delta$ -connected and the secondary coils 21, 22, 23 are Y-connected, the three-phase high frequency transformer 112 is suited as a transformer for step-up. Further, there is also the advantage that, when high frequency waves are included in the input, the high frequency waves circulate through the primary coils 11, 12, 13 that are  $\Delta$ -connected, and therefore, the high frequency waves do not mix with the output waves.

## 9. Embodiment 9

Of the three-phase high frequency transformers of the present invention, a second example in which the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected is described hereinafter.

A three-phase high frequency transformer 114 relating to embodiment 9 has a similar structure as the three-phase high frequency transformer 112 of embodiment 8 except that, as shown in FIG. 9A and FIG. 9B, the connecting member 40, that is formed from a plate-shaped conductor and has a triangular outer periphery whose respective vertices are rounded and in whose central portion is provided an opening portion of a similar shape as the outer periphery, is used as the connecting member that connects the lead lines 21B, 22B, 23B of the secondary coils 21, 22, 23, instead of the connecting member 30 in embodiment 8. Further, the operation as well is similar.

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## 10. Embodiment 10

Of the three-phase high frequency transformers of the present invention, a third example in which the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **116** relating to embodiment 10, differently from the three-phase high frequency transformer **112** of embodiment 8 and the three-phase high frequency transformer **114** of embodiment 9, the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** also are not bent in the vertical direction and are, while still in an winding end state, connected by the connecting member **50** in a vicinity of the floor plate **5C** as shown in FIG. **10A** and FIG. **10B**.

The connecting member **50** is formed from a plate-shaped conductor, and has a triangular outer periphery whose respective vertices are rounded, and an opening portion of a similar configuration as the outer periphery is provided in the central portion thereof. However, the connecting member **50** is positioned at the outer side of the bottom plate **5C**.

Further, the three-phase high frequency transformer **116** does not have the leg portions **9**, and instead, the bottom plate **5C** is directly placed on a substrate, and the fixing bolts **8** are screwed-together with screw holes provided in the substrate. Accordingly, the nuts **10** for fastening the upper half portion and the lower half portion of the three-legged ferrite core **5** are not needed.

At the three-phase high frequency transformer **116**, the structures of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13**, and the secondary coils **21**, **22**, **23**, and the connection of the lead lines **11A**, **11B**, **12A**, **12B**, **13A**, **13B** of the primary coils **11**, **12**, **13**, are the same as the three-phase high frequency transformer **112** of embodiment 8.

In addition to the features that the three-phase high frequency transformer **112** of embodiment 8 and the three-phase high frequency transformer **114** of embodiment 9 have, the three-phase high frequency transformer **116** has the feature that the post-processing of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** can be greatly simplified, and further, has the feature that the overall structure itself also can be simplified because the nuts **10** that screw-together with the fixing bolts **8** can be omitted.

## 11. Embodiment 11

Of the three-phase high frequency transformers of the present invention, a fourth example in which the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **118** relating to embodiment 11, differently from the three-phase high frequency transformer **112** of embodiment 8 and the three-phase high frequency transformer **114** of embodiment 9, the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** are bent downward and are connected by the connecting member **60** in a vicinity of the floor plate **5C** as shown in FIG. **11A** and FIG. **11B**.

At the three-phase high frequency transformer **118**, the structures of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13**, and the secondary coils **21**, **22**, **23**, and the connection of the lead lines **11A**, **11B**, **12A**, **12B**, **13A**, **13B** of the primary coils **11**, **12**, **13** are the same as the three-phase high frequency transformer **112** of embodiment 8.

The connecting member **60** has a triangular planar shape whose respective vertices are rounded, and is formed by

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bending a strip that is a conductor into this shape. The connecting member **60** is positioned at the outer side of the bottom plate **5C**.

Further, the three-phase high frequency transformer **118** does not have the leg portions **9**, and instead, the bottom plate **5C** is directly placed on a substrate, and the fixing bolts **8** are screwed-together with screw holes provided in the substrate. Accordingly, the nuts **10** for fastening the upper half portion and the lower half portion of the three-legged ferrite core **5** are not needed.

In addition to the feature that the overall structure itself also can be simplified because the nuts **10** that screw-together with the fixing bolts **8** can be omitted, the three-phase high frequency transformer **118** also has the feature that, because the connecting member **60** can be formed by bending a strip that is a conductor, manufacturing is easier as compared with the connecting member **50** that requires punching by a press or the like.

## 12. Embodiment 12

Of the three-phase high frequency transformers of the present invention, a fifth example in which the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **120** relating to embodiment 12, as shown in FIG. **12A** and FIG. **12B**, the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** are bent downward, and are inserted in the opening portions **73** that are provided in the printed circuit board **70**. Here, the connected pattern **71** is formed at the portions where the opening portions **73** are formed at the reverse of the printed circuit board **70**, so as to connect the three opening portions **73**. Further, the lead lines **21B**, **22B**, **23B** are soldered to the connected pattern **71** at the opening portions **73**. Due thereto, the lead lines **21B**, **22B**, **23B** are connected at the connected pattern **71**.

Further, the fixing bolt **8** is inserted-through a hole provided in the printed circuit board **70**, and the nut **10** is screwed-together from the reverse side of the printed circuit board **70**.

At the three-phase high frequency transformer **120**, the structures of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23**, and the connection of the lead lines **11A**, **11B**, **12A**, **12B**, **13A**, **13B** of the primary coils **11**, **12**, **13** are the same as the three-phase high frequency transformer **112** of embodiment 8.

In addition to the features that the three-phase high frequency transformer **112** of embodiment 8 has, the three-phase high frequency transformer **120** has the feature that mounting on the printed circuit board **70** can be done easily.

## 13. Embodiment 13

Of the three-phase high frequency transformers of the present invention, a sixth example in which the primary coils are  $\Delta$ -connected and the secondary coils are Y-connected is described hereinafter.

In a three-phase high frequency transformer **122** relating to embodiment 13, as shown in FIG. **13A** and FIG. **13B**, the final ends of the lead lines **21B**, **22B**, **23B** of the secondary coils **21**, **22**, **23** are bent upward, and are respectively connected at the connecting member **80** that is substantially triangular. The connecting member **80** is a triangular shape whose ridge portions project-out to the outer side. The distal ends of the ridge portions are bent downward and are connected to the lead lines **21B**, **22B**, **23B**.



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Other than the above-described points, the three-phase high frequency transformer **122** has the same structure as the three-phase high frequency transformer **112** of embodiment 8.

## 14. Embodiment 14

Of the three-phase high frequency transformers of the present invention, an example in which the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected is described hereinafter.

In a three-phase high frequency transformer **124** relating to embodiment 14, as shown in FIG. **14A** and FIG. **14B**, the primary coils **11**, **12**, **13** are all formed by winding flat wires upward from bottom to top, and the winding start portions are made to be the lead lines **11A**, **12A**, **13A** respectively, and the winding end portions are made to be the lead lines **11B**, **12B**, **13B** respectively.

Further, the lead lines **11B**, **12B**, **13B** of the winding end sides are respectively bent upward, and further, at the final end portions, are bent horizontally so as to be directed toward the inner side, and are connected to the connecting member **30**. The connecting member **30** is as described in embodiment 1.

On the other hand, the lead lines **11A**, **12A**, **13A** of the winding start sides are connected to the U-phase, the V-phase, the W-phase of the input side, respectively. Accordingly, the primary coils **11**, **12**, **13** are Y-connected.

On the other hand, the secondary coils **21**, **22**, **23** are formed by winding flat wires, whose width is wider than the primary coils **11**, **12**, **13**, downward from top to bottom. The winding start portions are made to be the lead lines **21A**, **22A**, **23A** respectively, and the winding end portions are made to be the lead lines **21B**, **22B**, **23B** respectively.

The lead lines **21A**, **22A**, **23A** of the winding start sides are respectively bent downward, and the final ends thereof are at substantially the same height as the lead lines **21B**, **22B**, **23B** of the winding end sides. Further, the lead line **21B** at the winding end side of the secondary coil **21** is connected to the lead line **23A** at the winding start side of the secondary coil **23**, the lead line **23B** at the winding end side of the secondary coil **23** is connected to the lead line **22A** at the winding start side of the secondary coil **22**, and the lead line **22B** at the winding end side of the secondary coil **22** is connected to the lead line **21A** at the winding start side of the secondary coil **21**. Further, the connected portion of the lead line **21B** and the lead line **23A**, the connected portion of the lead line **23B** and the lead line **22A**, and the connected portion of the lead line **22B** and the lead line **21A** are connected to the U-phase, the V-phase, the W-phase of the output side respectively. Accordingly, the secondary coils **21**, **22**, **23** are  $\Delta$ -connected.

Other than the above-described points, the three-phase high frequency transformer **124** has the same structure as the three-phase high frequency transformer **100** of embodiment 1.

At the three-phase high frequency transformer **124** as well, the upper half portions of the columnar cores **5A** and the ceiling plate **5B**, and the lower half portions of the columnar cores **5A** and the bottom plate **5C** are formed integrally, and respectively structure the upper half portion and the lower half portion of the three-legged ferrite core **5**. Further, because the upper half portion and the lower half portion of the three-legged ferrite core **5** are strongly fastened by the fixing bolts **8** that are inserted-through the bolt insert-through hole **6** and the bolt insert-through grooves **7**, no air gaps are formed between the columnar cores **5A** and

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the ceiling plate **5B** and the bottom plate **5C**, and between the upper half portions and the lower half portions of the columnar cores **5A**, and therefore, an increase in iron loss due to the existence of air gaps can be effectively suppressed.

Further, because the inner diameters of the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23** are equal, and further, the inner peripheries are disposed so as to coincide, the gaps between the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23**, and the columnar cores **5A**, are narrow, and therefore, even when used at high frequencies, a high conversion efficiency can be achieved.

Moreover, because the primary coils **11**, **12**, **13** are Y-connected and the secondary coils **21**, **22**, **23** are  $\Delta$ -connected, the three-phase high frequency transformer **124** is suitable as a transformer for large electric power. Further, there is also the advantage that, when high frequency waves are included in the input, the high frequency waves circulate through the secondary coils **21**, **22**, **23** that are  $\Delta$ -connected, and the high frequency waves do not mix with the output waves.

## 15. Embodiment 15

Of the three-phase high frequency transformers of the present invention, a second example in which the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected is described hereinafter.

As shown in FIG. **15A** and FIG. **15B**, a three-phase high frequency transformer **126** relating to embodiment 15 has a similar structure as the three-phase high frequency transformer **124** of embodiment 14 except that the connecting member **40**, that is formed from a plate-shaped conductor and has a triangular outer periphery whose respective vertices are rounded and in whose central portion is provided an opening portion of a similar shape as the outer periphery, is used as the connecting member that connects the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13**; instead of the connecting member **30** in embodiment 14. Further, the operation as well is similar.

## 16. Embodiment 16

Of the three-phase high frequency transformers of the present invention, a third example in which the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected is described hereinafter.

In a three-phase high frequency transformer **128** relating to embodiment 16, differently from the three-phase high frequency transformer **124** of embodiment 14 and the three-phase high frequency transformer **126** of embodiment 15, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** are not bent in the vertical direction and are, while still in an winding end state, connected by the connecting member **50** in a vicinity of the ceiling plate **5B** as shown in FIG. **16A** and FIG. **16B**.

The connecting member **50** all is formed from a plate-shaped conductor, and has a triangular outer periphery whose respective vertices are rounded, and an opening portion of a similar configuration as the outer periphery is provided in the central portion thereof. However, the connecting member **50** is positioned at the outer side of the ceiling plate **5B**.

Further, the three-phase high frequency transformer **128** does not have the leg portions **9**, and instead, the bottom plate **5C** is directly placed on a substrate, and the fixing bolts **8** are screwed-together with screw holes provided in the

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substrate. Accordingly, the nuts **10** for fastening the upper half portion and the lower half portion of the three-legged ferrite core **5** are not needed.

At the three-phase high frequency transformer **128**, the structures of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13**, and the secondary coils **21**, **22**, **23**, and the connection of the lead lines **21A**, **21B**, **22A**, **22B**, **23A**, **23B** of the secondary coils **21**, **22**, **23**, are the same as the three-phase high frequency transformer **124** of embodiment 14.

In addition to the features that the three-phase high frequency transformer **124** of embodiment 14 and the three-phase high frequency transformer **126** of embodiment 15 have, the three-phase high frequency transformer **128** has the feature that the post-processing of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** can be greatly simplified, and further, has the feature that the overall structure itself also can be simplified because the nuts **10** that screw-together with the fixing bolts **8** can be omitted.

## 17. Embodiment 17

Of the three-phase high frequency transformers of the present invention, a fourth example in which the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected is described hereinafter.

In a three-phase high frequency transformer **130** relating to embodiment 17, differently from the three-phase high frequency transformer **124** of embodiment 14 and the three-phase high frequency transformer **126** of embodiment 15, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** are bent upward and are connected by the connecting member **60** in a vicinity of the ceiling plate **5B** as shown in FIG. 17A and FIG. 17B.

At the three-phase high frequency transformer **130**, the structures of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13**, and the secondary coils **21**, **22**, **23**, and the connection of the lead lines **21A**, **21B**, **22A**, **22B**, **23A**, **23B** of the secondary coils **21**, **22**, **23** are the same as the three-phase high frequency transformer **124** of embodiment 14.

The connecting member **60** has a triangular planar shape whose respective vertices are rounded, and is formed by bending a strip that is a conductor into this shape. The connecting member **60** is positioned at the outer side of the bottom plate **5C**.

Further, the three-phase high frequency transformer **130** does not have the leg portions **9**, and instead, the bottom plate **5C** is directly placed on a substrate, and the fixing bolts **8** are screwed-together with screw holes provided in the substrate. Accordingly, the nuts **10** for fastening the upper half portion and the lower half portion of the three-legged ferrite core **5** are not needed.

In addition to the feature that the overall structure itself also can be simplified because the nuts **10** that screw-together with the fixing bolts **8** can be omitted, the three-phase high frequency transformer **130** also has the feature that, because the connecting member **60** can be formed by bending a strip that is a conductor, manufacturing is easy as compared with the connecting member **50** that requires punching by a press or the like.

## 18. Embodiment 18

Of the three-phase high frequency transformers of the present invention, a fifth example in which the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected is described hereinafter.

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In a three-phase high frequency transformer **132** relating to embodiment 18, as shown in FIG. 18A and FIG. 18B, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** are bent downward, and are inserted in the opening portions **73** that are provided in the printed circuit board **70**. Here, the connected pattern **71** is formed at the portions where the opening portions **73** are formed at the reverse of the printed circuit board **70**, so as to connect the three opening portions **73**. Further, the lead lines **11B**, **12B**, **13B** are soldered to the connected pattern **71** at the opening portions **73**. Due thereto, the lead lines **11B**, **12B**, **13B** are connected at the connected pattern **71**.

Further, the fixing bolt **8** is inserted-through a hole provided in the printed circuit board **70**, and the nut **10** is screwed-together from the reverse side of the printed circuit board **70**.

At the three-phase high frequency transformer **132**, the structures of the three-legged ferrite core **5**, the primary coils **11**, **12**, **13** and the secondary coils **21**, **22**, **23**, and the connection of the lead lines **21A**, **21B**, **22A**, **22B**, **23A**, **13B** of the secondary coils **21**, **22**, **23**, are the same as the three-phase high frequency transformer **124** of embodiment 14.

In addition to the features that the three-phase high frequency transformer **124** of embodiment 14 has, the three-phase high frequency transformer **132** has the feature that mounting to the printed circuit board **70** can be done easily.

## 19. Embodiment 19

Of the three-phase high frequency transformers of the present invention, a sixth example in which the primary coils are Y-connected and the secondary coils are  $\Delta$ -connected is described hereinafter.

In a three-phase high frequency transformer **134** relating to embodiment 19, as shown in FIG. 19A and FIG. 19B, the final ends of the lead lines **11B**, **12B**, **13B** of the primary coils **11**, **12**, **13** are bent upward, and are respectively connected at the connecting member **80** that is substantially triangular. The connecting member **80** is a triangular shape whose ridge portions project-out to the outer side. The distal ends of the ridge portions are bent downward and are connected to the lead lines **11B**, **12B**, **13B**.

Other than the above-described points, the three-phase high frequency transformer **134** has the same structure as the three-phase high frequency transformer **124** of embodiment 14.

The invention claimed is:

1. A three-phase high frequency transformer comprising: three solid-cylindrical cores that are formed of ferrite and that are disposed at uniform intervals on a circumference; a ceiling plate formed of ferrite and connected to first ends of the solid-cylindrical cores; a bottom plate formed of ferrite and connected to second ends of the solid-cylindrical cores; and three sets of coils having primary coils of a predetermined inner diameter formed by flat wires wound edgewise, and secondary coils that have an inner diameter that is the same as the inner diameter of the primary coils and are formed of flat wires wound edgewise, the flat wires forming the secondary coils having at least one of a width or a thickness different than those of the flat wires forming the primary coils, each of the flat wires of the primary coils and the secondary coils having a larger measurement in a width direction than in a thickness direction,

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wherein the primary coils and the secondary coils are configured such that high frequency current flows therein,  
 wherein both the primary coils and the secondary coils are helical coils,  
 wherein the flat wires structuring the secondary coils are inserted within intervals of the flat wires structuring the primary coils, or the flat wires structuring the primary coils are inserted within intervals of the flat wires structuring the secondary coils, and the three sets of coils are structured such that inner peripheries of the primary coils and inner peripheries of the secondary coils coincide, and are disposed such that the respective solid-cylindrical cores are inserted in respective inner portions of the three sets of coils,  
 wherein the primary coils and the secondary coils are  $\Delta$ -connected,  
 wherein each of the three primary coils of the three sets of coils is  $\Delta$ -connected by connecting one end of one primary coil to the other end of another primary coil by a first connecting line,  
 wherein each of the three secondary coils of the three sets of coils is  $\Delta$ -connected by connecting one end of one secondary coil to the other end of another secondary coil by a fourth connecting line,  
 wherein the first connecting line is a conductor associated with each of the three primary coils and arranged outside each of the three sets of coils and extending along the solid-cylindrical cores,  
 wherein the fourth connecting line is a conductor associated with each of the three secondary coils and arranged outside each of the three sets of coils and extending along the solid-cylindrical cores,

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wherein at least the first connecting line is a plate-shaped conductor that comprises a vertical section and a horizontal section; the first connecting line is disposed at the side of one of the top plate core and the bottom plate core along one of the upper and lower surface of one of the top plate and bottom plate core,  
 wherein at least one winding end portion of one of the primary coils is connected by a bolt to the upper end of the first connecting line in the vertical direction and another primary coil has a winding end portion that is connected to the lower end of first connection line that is bent in the horizontal direction,  
 wherein at least the fourth connecting line is a plate-shaped conductor that comprises a vertical section and a horizontal section, the fourth connecting line is disposed at side of one of the top plate core and the bottom plate core along one of the upper and lower surface of one of the top plate and bottom plate core, and  
 wherein at least one winding end portion of one of the secondary coils is connected by a bolt to the upper end of the fourth connecting line in the vertical direction and another secondary coil has a winding end portion that is connected to the lower end of fourth connection line that is bent in the horizontal direction.  
**2.** The three-phase high frequency transformer of claim 1 wherein a bolt-insert through groove is formed at the central portion of each side of the ceiling plate and at the central portion of each side of the bottom plate, and  
 wherein a fixing bolt for fastening the ceiling plate, the solid-cylindrical cores, and the bottom plate is inserted through the bolt insert-through groove.

\* \* \* \* \*